OVERSIGHT OF THE FISCAL YEAR 1989 EPA RESEARCH BUDGET REQUEST

HEARING

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

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OVERSIGHT OF THE FISCAL YEAR 1989 EPA RESEARCH BUDGET REQUEST

THURSDAY, APRIL 21, 1988

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2:10 p.m., in Room 2325, Rayburn House Office Building, Hon. James H. Scheuer [chairman of the subcommittee] presiding.

Mr. SCHEUER. Good afternoon.

The Subcommittee on Natural Resources, Agriculture Research and Environment will come to order.

Today we will review the Administration's 1989 request for research programs at EPA.

Since the House has already passed H.R. 2355, which includes the authorization for fiscal year 1989 research programs, we don't expect to mark up any further additional authorizing legislation this year. The purpose then of this hearing is to give us the opportunity to review the budget request and to examine the proposed direction of EPA's future research program.

The Administration has requested $375 million for fiscal year 1989, which is a modest increase of about 6 percent—slightly more than 6 percent, just under $23 million—over the present level. And it seems appropriate to us, since this is President Reagan's last year in office and this is the last budget under his aegis, for us to look back over the span of the last seven and a half years and see what mark the Reagan era has left on EPA's research programs.

Now, at first glance, EPA's fiscal 1989 programs appear generous. Indeed, one has to say, in all fairness, that it is the highest level of funding for research, environmental research that EPA has ever requested. But on closer analysis the picture is not quite so rosy, for terms of purchasing power, in terms of real dollars, EPA's research budget has been cut a fifth, one fifth during President Reagan's tenure.

And this has come at a time when EPA has been charged with significant new responsibilities, both under Superfund, the Clean Water Act, the Solid Waste Disposal Act, and the Safe Water Drinking Act, inter alia, and the shift in funding within the EPA family of programs, so to speak, has also had a significant detrimental result to very important research programs.

Two programs which scarcely existed in 1980, or early 1981, acid rain research and Superfund research, now account for one dollar out of every three that EPA spends on environmental research.

So, if you take out those two dollars—those two programs, if you set them aside, and you crank in the impact of inflation, you find that all of the other research programs, apart from acid rain and superfund research, have been cut 50 percent in real dollars since the beginning of the Reagan era. And I would have to say that we have cut by 50 percent EPA's actual on the job, hands-on capability of protecting the nation's health and environment. That is a very serious situation.

We very critically lack an adequate knowledge base and an adequate information base to identify and assess critical, emerging environmental problems, like global warming, like the ground water contamination, like indoor air pollution. Now, there are some encouraging signs on the horizon.

Many groups out there, non-profit groups and perhaps EPA itself, have begun to acknowledge the crisis that has been created during this Administration. For example, EPA's prestigious Science Advisory Board has called for significantly increased funding and for the establishment of an in-house group to assess and identify emerging environmental issues.

One hopes that it's not too late for this Administration, in the waning months of the year, to take remedial action. But in any event, we hope that the Science Advisory Board will chart the way for the next Administration, of whatever party.

The EPA has encouraged the Society for Environmental Toxicology and Chemistry to convene a workshop of leading scientists from academia, Government, industry and non-profit environmental groups to evaluate the needs, unmet needs, and they have recommended a $750 million program, spread over ten years, to do research on environmental risk assessment.

Third—or next, the Association of Environmental Engineering Professors has warned of the crisis in trained manpower we will reach without an increased investment in training grants and basic university research. They have identified this as a major challenge and a major problem area.

An EPA consultant recently warned that due to the lack of adequate funding EPA's University Research Program is on the verge of collapse, and of course, this would leave several critical areas of environmental research virtually unfunded by the Federal Government.

Lastly, Lee Thomas has commissioned Al Alm, a former Deputy Administrator of EPA, to head up a special task force on long-term research at EPA, and his report, expected by the fall, may well provide a basis for moving ahead to revamp the EPA research program in the post-Reagan era.

And there are even some encouraging signs within this budget itself. In particular, the proposed $8 million increase in stratospheric ozone research is a welcome, if belated, recognition of the need to understand the possible aquatic and ecological effects of the destruction of the ozone layer. And I also personally welcome the $1.9 million funding for a new modern biotechnology facility which finally, at long last, reflects the understanding that EPA

must have cutting edge technology to keep pace with technological developments.

And I do want to say, as we consider this last EPA research budget under—requested by the Reagan Administration, that I very much appreciate the efforts of the witnesses, today and in past months, to inform us about the directions for EPA research in the years to come, and I give them a cordial welcome.

So, Dr. Newill, why don't we start out with you. Why don't you take 10 or 12 minutes to sum up your testimony and I'm sure we'll have some questions for you.

Will Mr. Bretthauer be testifying?

Mr. BRETTHAUER. I will answer some questions.

Mr. SCHEUER. Okay, very good.

Okay, Dr. Newill, we're very happy to have you here. We appreciate your cooperation in helping us set up this hearing. Please proceed for 10 or 12 minutes.

STATEMENT OF DR. VAUN NEWILL, ASSISTANT ADMINISTRATOR FOR RESEARCH, AND DEVELOPMENT, ENVIRONMENTAL PROTECTION AGENCY; ACCOMPANIED BY ERIC BRETTHAUER, ACTING DEPUTY ASSISTANT ADMINISTRATOR, OFFICE OF RESEARCH AND DEVELOPMENT, AND ROGER CORTESI, DIRECTOR, OFFICE OF EXPLORATORY RESEARCH; DR. MORTON LIPPMANN, INSTITUTE OF ENVIRONMENTAL MEDICINE, NEW YORK UNIVERSITY, EPA SCIENCE ADVISORY BOARD

Dr. NEWILL. Thank you very much, Mr. Chairman.

My colleagues and I are pleased to have this opportunity to discuss the proposed fiscal year 1989 research and development program of the Environmental Protection Agency.

As you have said, our request is for $375 million and 1,848 work years. Compared with fiscal year 1988, the proposed budget represents an increase of $22.7 million and 17 work years.

Since the total statement is going to appear in the record, I'll just make a statement or two about each environmental medium and a couple of other statements.

First, for a research organization whose projects take considerable time, even years, from inception to completion, the proposed budget provides some stability for our on-going endeavors. Second, it provides a very important increase in our intramural resources to revitalize our laboratory infrastructure. Finally, even in these days of fiscal austerity, the proposed budget does provide increase for several important emerging areas, which I'll touch on later.

In the air research program we propose an overall increase of $6.7 million. This increase permits us to expand our research on the effects of increased ultraviolet radiation on plants, marine ecosystems and human health, which may result from the depletion of stratospheric ozone.

In the area of air research, the Global Climate Protection Act of 1987 gives EPA important additional research responsibilities. The proposed budget of $3.2 million provides a program in the area of global climate change.

In the area of ionizing radiation the proposed budget shows an increase of $1.1 million for a total of $4 million. This helps us to

develop and evaluate additional techniques for mitigating the adverse health impacts of radon, as well as to expand our post-mitigation diagnosis efforts in home demonstration sites.

Our proposed water research program is essentially stable.

In the area of drinking water research there is a small decrease of a half million dollars, but we are asking for a very credible $22 million program.

In the area of pesticides research the proposed budget contains an increase of $1.5 million. This growth is attributable to our increased effort regarding disposal technologies for cancelled and suspended pesticides, and continuing our efforts in the area of biotechnology.

And as you've already mentioned, under the agency's building and facilities account, $1.9 million is included for the new biotechnology laboratory in Gulf Breeze, Florida.

The proposed toxics research program remains essentially stable.

Hazardous waste and superfund are highly complementary in nature. In the proposed budget the hazardous waste research program shows a decrease of $3.4 million. However, in the superfund budget there is an increase of almost $8.4 million. The $3.4 million reduction is mainly due to completing our support of the Tufts Center for Environmental Management.

We believe that this Center has gotten off to a strong start, and by fiscal year 1989 should be able to maintain itself completely by attracting funding sources.

For the superfund research program the proposed budget totals $66.8 million. This level continues our support of EPA regional offices in the superfund clean up effort. We are implementing the superfund innovative technology evaluation, the SITE program, to encourage the private sector to develop and use innovative clean up technologies.

The budget provides $5 million for the five hazardous substance research centers which we are establishing this year. It also provides an increase of $4.7 million for a new initiative we are calling biosystems that will develop subsurface biological, chemical and physical processes that promote *in situ* biodegradation.

In the area of multi-media energy research the proposed budget continues at $55.4 million. Under the Acid Rain Research Program we are continuing our work to relate the emission acid precursors to deposition patterns and ecological effects.

The remainder of the multi-media energy research program deals with the demonstration of the limestone injection multi-stage burner technology.

The proposed inter-disciplinary research program budget represents an increase of $7.2 million. This increase allows us to fund the Congressionally mandated program in reducing uncertainty and risk assessment at a level of $10 million.

Finally, Mr. Chairman, as I indicated earlier, the proposed budget provides increased resources for the intramural program. This increase is $3.2 million and is included in the agency's salaries and expense category. It will provide for maintaining the equipment and in-house research capability.

Mr. Chairman, this concludes my presentation of the highlights of our proposed fiscal year 1989 program. My colleagues and I are prepared to entertain your questions.

[The prepared statement of Dr. Vaun Newill follows:]

STATEMENT OF
VAUN A. NEWILL, MD
ASSISTANT ADMINISTRATOR
FOR RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
BEFORE THE
SUBCOMMITTEE ON NATURAL RESOURCES,
AGRICULTURE RESEARCH AND ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

April 21, 1988

Good morning Mr. Chairman and Members of the Subcommittee. My colleagues and I are pleased to have this opportunity to discuss the proposed Fiscal Year 1989 research and development program of the Environmental Protection Agency.

In FY 1989, the President is requesting an EPA research and development budget of $375.0 million and 1848 workyears. Compared with FY 1988, the proposed budget represents an increase of $22.7 million and 17 workyears.

While I will go into greater detail shortly, there are several general characteristics of the proposed budget which seem worthy of note. First, for a research organization whose projects take considerable time, even years, from inception to completion, the proposed budget provides needed stability for our on-going endeavors. Second, it provides a very important increase in our intramural resources to revitalize our laboratory

infrastructure. Finally, even in these days of fiscal austerity, the proposed budget does provide increases for several important emerging areas, especially: stratospheric ozone depletion, global climate change, reduction of uncertainty in risk assessment, radon mitigation and expanded research and development in support of the Agency's Superfund program.

As you know, the Agency implements environmental legislation which, like most of the Agency's offices, is structured along lines of environmental media such as air and ionizing radiation, water and drinking water, pesticides and toxic substances, etc. I would now like to briefly highlight our activities in these major areas.

In the air research program, we propose an overall increase of $6.7 million to a total of $72.5 million. This increase permits us to expand our research on the effects of increased ultraviolet B-band (UV-B) radiation on plants, marine ecosystems, and human health, which may result from depletion of stratospheric ozone. The signing of the Montreal stratospheric ozone protocol by the U.S. represents a major international achievement and commits us to provide scientific assessments in 1990 and 1994 of the likely impact of stratospheric ozone depletion. Further, in the area of air research, the Global Climate Protection Act of 1987 gives EPA important additional research responsibilities. The proposed budget provides a $3.2

million program in the area of global climate change. This is an increase of about $0.5 million. Also, in the air program, we are proposing a modest $0.4 million increase in the area of indoor air pollution research.

In the area of ionizing radiation R&D, the proposed budget shows an increase of $1.1 million, for a total of $4.0 million. This budget enables us to develop and evaluate additional techniques for mitigating the adverse health impacts of radon, as well as to expand our post-mitigation diagnosis efforts in home demonstration sites. We are also continuing to provide radiological monitoring support to the Department of Energy Nevada Test Site and other installations, and quality assurance assistance to Federal, State, and local laboratories.

Our proposed water research program is essentially stable, with a minor increase of $0.3 million to a total of $25.1 million. This proposed budget continues our support of the Agency's efforts to protect wetlands and to assess the impacts of wetland conversions and permits us to develop risk assessment procedures to evaluate the impacts from waste disposal in coastal and deep ocean water. We are continuing our existing level of support for the Great Lakes program, which includes in-place pollutant transportinvestigations and technical support to EPA's Great Lakes National Program Office, to bordering regions and States, and to the International Joint Commission.

In the area of drinking water research, there is a small decrease of $0.5 million, but we are asking for a very credible $22.0 million program. The research program continues to provide health assessment information to support the Office of Drinking Water in developing revised regulations to control water contaminants, to assess the impacts of by-products from chemical disinfection, and to improve methods for predicting transport, transformation, and fate of ground water contaminants.

In the area of pesticides research, the proposed budget contains an increase of $1.5 million to a total of $14.4 million in FY 1989. This growth is attributable to our increased effort regarding disposal technologies for cancelled and suspended pesticides. This work includes continued testing and related technical support activities for dealing with Dinoseb, 2,4,5-T, and Silvex. We are also continuing our efforts in the area of biotechnology, an effort that includes research on the health and environmental effects of biotechnology products and work in containment and mitigation technologies, worker exposure and environmental monitoring. Under the Agency's Buildings and Facilities account, $1.9 million is included for the design and construction of a new biotechnology laboratory at our Gulf Breeze, FL, facility. Our research on the effects of pesticide use on ground water will continue as well.

The proposed toxics research program remains essentially stable at $26.6 million in 1989. In this area, our program continues to emphasize the assessment of the health and environmental risk of toxic chemicals, including developing models to predict the manufacturing waste release of and exposure to new and existing chemicals. Also, we will continue to conduct research dealing with the evaluation of new abatement and monitoring technologies for asbestos.

The next two major research areas, hazardous waste and Superfund, are highly complementary in nature. In the proposed budget, the hazardous waste research program shows a decrease of $3.4 million; however, the Superfund budget shows an increase of almost $8.4 million.

The budget for the hazardous waste program is $41.3 million. This level permits us to continue our emphasis on the assessment of emissions from municipal waste incinerators and the development of improved risk assessment methodologies. The $3.4 million reduction is mainly due to completing our support of the Tufts Center for Environmental Management. We believe that this Center has gotten off to a strong start and by FY 1989 should beable to maintain itself competitively by attracting funding sources for specific projects from private and government sources.

For the Superfund research program, the proposed budget totals $66.8 million. This level continues our support of EPA regional offices in the Superfund clean-up effort by providing health and environmental risk assessment research and guidance on suitable monitoring and clean-up technologies. We are implementing the Superfund Innovative Technology Evaluation (SITE) program to encourage the private sector to develop and use innovative clean-up technologies. We have already demonstrated a number of technologies and are continuing to solicit proposals for the SITE program. The budget provides $5.0 million for the five Hazardous Substances Research Centers, which we are establishing this year. It also provides an increase of $4.7 million for a new initiative we are calling biosystem that will develop subsurface biological, chemical, and physical processes that promote in situ biodegradation. We are developing new application techniques and technologies for environmental and worker protection during site cleanups.

In the area of multi-media energy research, the proposed budget continues a $55.4 million program. The acid rain research program is performed as part of the National Acid Precipitation Assessment Program (NAPAP). We are continuing our work to relate the emission acid precursors to deposition patterns and ecological effects. The remainder of the multi-media energy research program

deals with the demonstration of the limestone injection multi-stage burner (LIMB) technology. This project provides final documentation of the wall-fired utility boiler demonstration and continues support for the tangentially-fired boiler demonstration.

The proposed interdisciplinary research program budget represents an increase of $7.2 million to a total of $34.1 million in FY 1989. This increase allows us to fund the Congressionally mandated program on reducing uncertainty in risk assessment at a level of $10.0 million, which is up from $3.0 million in FY 1988. Of this $10.0 million, about $7.0 million is devoted to human health risk assessment research and $3.0 million is devoted to ecological risk assessment research. The remainder of the interdisciplinary program, which supports areas such as: exploratory grants, exploratory research centers, provides scientific assessment and regulatory support, and funds technology transfer activities, will be funded at about the same level as in FY 1988.

Finally Mr. Chairman, as I indicated earlier, the proposed budget provides increased resources for the intramural program. This increase is $3.2 million and is included in the Agency's Salaries and Expense category. It will provide for maintaining the equipment and in-house research cability. I am particularly pleased that the

Administrator and the President concurred in this even in these times of tight budgets.

Mr. Chairman, this concludes my presentation of the highlights of our proposed FY-1989 program. My colleagues and I are prepared to entertain any questions you may have.

* * *

Mr. SCHEUER. Very good. Thank you very much.

An EPA contractor, American Management Systems, has just finished a report on EPA's Exploratory Research Contracts Programs. Are you familiar with that, Dr. Newill?

Dr. NEWILL. Yes, I have seen the report. Actually, we just received it two days ago.

Mr. SCHEUER. Well, it paints a rather bleak program—a bleak picture of EPA's environmental research grants and indicates that the program is severely and painfully underfunded. Do you agree with that assessment? Do you agree with the conclusions of the report?

Dr. NEWILL. I think that essentially we don't disagree with it.

Mr. SCHEUER. The report indicates that the program accounts for about one-fourth of all Federal grant funds available to university researchers. These are just for non- health environment research relevant to EPA.

The report also found, contrary to past assertions made by the Office of Management and Budget, that EPA's grants do go to research that would not be funded by any other Federal agency.

Do you have any quarrel with that?

Dr. NEWILL. No.

Mr. SCHEUER. The report also found that the low- level of funding for this program is terribly frustrating to university scientists who simply can't afford to continue to submit proposals which are never funded. The report even quotes the former Assistant Director of EPA's Office of Research and Development, quotes him as advising his faculty not even to bother replying to EPA.

Any problem with those statements?

Dr. NEWILL. I certainly have problems with them, but I understand them.

Mr. SCHEUER. All right.

About how many grant applications are you expecting to receive this fiscal year?

Dr. NEWILL. About 300.

Mr. SCHEUER. Based on past experience, Dr. Newill, about how many or what percentage of these 300 applications are likely to be judged by peer reviewers as having significant scientific merit?

Dr. NEWILL. About 100 of them.

Mr. SCHEUER. How many of those 100, theoretically, meritorious grants are likely to be funded?

Dr. NEWILL. This is the wrong year to ask that question.

Mr. SCHEUER. Pardon?

Dr. NEWILL. This is the wrong year to ask that question. There will be none of them funded.

Mr. SCHEUER. None of them funded?

Dr. NEWILL. No, none

Mr. SCHEUER. It's that bad?

Dr. NEWILL. The monies that are available will be used to fund the grants that are in place for their second and third years and there will be no monies left over for new starts this year. So that these grants will in fact be saved until next year and will compete in the funding next year, but they will wait a year for that.

Mr. SCHEUER. Are the environmental problems going to wait for that year—

Dr. NEWILL. No, sir.

Mr. SCHEUER. Pardon?

Dr. NEWILL. No, sir.

Mr. SCHEUER. This is not a personal criticism of you at all, Dr. Newill, but I couldn't help asking whether all those problems that are festering out there, are they going to wait for a year or two, until our funding catches up with the urgent need to evaluate and analyze and probe these problems?

Dr. NEWILL. The problems will not wait, but we're also—

Mr. SCHEUER. Is the Office of Management and Budget—do you think they would concur in that statement of yours?

That's an unfair question. I withdraw that.

Well, now, are you inviting—this year are you inviting university researchers to apply for grants when you have no money?

Dr. NEWILL. Yes. Let me tell you about—I mean, let me have someone tell you about the sequence so you understand why we have a solicitation in the field when we have no money for new grants.

Roger, can you—

Mr. SCHEUER. Come to a microphone.

Dr. NEWILL. This is Roger Cortesi, the Office Director, the Office of Exploratory Research.

Mr. CORTESI. How do you do.

Mr. SCHEUER. How are you. We're very happy to have you here.

Mr. CORTESI. It's a pleasure to be here, I assure you.

In the past, the Congress has felt that the President's request for grants should be augmented to the tune of $3 to $4 million every year.

Mr. SCHEUER. What percentage augmentation would that be?

Mr. CORTESI. That would be about—between 20 and 33 percent. Between a fifth and a third, depending on where we are.

The grant program has been traditionally run in that we fund with available money, continuations first, and then, what is left over, is used for new starts.

The solicitation statement for grants goes out just about the beginning of the fiscal year. This year, as you know, an appropriation act did not finally make it out of the Congress and through the White House until very much later than that, and the question arose, at the time when we were sending this solicitation out, about whether we should cancel the solicitation on the grounds of no assurance of funds being available. We decided not to cancel because we felt that would look like trying to force Congress' hand and we did not wish to look like we were playing games, either with Congress or with the Administration. So, we sent the solicitation out as we usually do.

As I say, there was a long history of the Congress adding money to the President's request, so we did not feel that this was a rash and injudicious thing to do.

Mr. SCHEUER. Dr. Newill, in your opinion, what level of funding would be appropriate, necessary to have a credible and viable science program?

Dr. NEWILL. I think I'm going to take the liberty of wearing two hats in this hearing, if you don't mind. Sometimes I'll be speaking as the manager and the AA for ORD and sometimes I'll try to be

speaking as a scientist, and I think at least the first part of this answer will be as a scientist.

I think that the minimum credible investigator initiated grant program is about 125 new starts each year, and I think that in fiscal year 1989 that would imply an additional $8 to $9 million, a steady state budget of about $35 million per year.

But also, I don't believe we could squeeze that—this is the manager's hat going back on. I don't think we could squeeze that out of our R&D budget this year, particularly with Gramm-Rudmann-Hollings and the other deficit induced concerns.

So, that's where I'm caught. But I know there's a great deal of concern, even with our Administrator in this regard. He would like to see this program funded better than it is also. In fact, I'm sure he would be willing to talk to you about this.

Mr. SCHEUER. Well, we'll ask him down.

We've got so many—I'll put it this way. Our ability to measure, which has improved a quantum jump, by a quantum jump over the last decade, decade and a half—there's a whole new awareness of some of the problems out there. We had no way of evaluating or analyzing or assessing the decade or more ago.

Let's take the Greenhouse effect. It's a global environmental problem which could have devastating effects all over the world.

Your fiscal year 1989 budget calls for a very modest continued program of about $3 million. EPA was given responsibility for coordinating Federal policy decisions under the Global Climate Protection Act passed last year. You must inevitably ask the question, why hasn't EPA asked for significantly more resources to carry out its new responsibilities under the Global Climate Protection Act.

Dr. NEWILL. Yes. Well, let me give maybe a longer answer that you might have wanted to this.

Mr. SCHEUER. Oh, no.

Dr. NEWILL. First of all, in terms of coordination, there are two kinds of coordination. There's policy coordination and there is science coordination. The policy coordination, at least up to this point in time, has been primarily informal and it is working, although it has to become more formal than it has been up to this point in time, and our Administrator is making real efforts to make this more formal.

And that—the coordination, for example, relative to stratospheric ozone depletion is working very well. That one is moving ahead much more rapidly than the Global Climate one is.

In terms of the science coordination, there's coordination that takes place under the NPLO—oh, yes, the National Climate Program Office. It's NCPO. And there's also coordination that takes place under the Federal Coodinating Committee for Science, Engineering & Technology (FCCSET), the Subcommittee on Earth Sciences, and these are both active and beginning to work with coordination.

So that there is science coordination that is beginning to take place at the present time, so there are five appropriate agencies: DOE, EPA, NOAA, NASA, USGS.

Mr. SCHEUER. What is the EPA's role, coordinating or otherwise, on the Greenhouse issue in terms of the other Federal agencies that have been involved?

Dr. NEWILL. In the policy area, Mr. Thomas is trying to make the coordination more formal. He has the direct responsibility to do that.

I'm not sure that we have quite the same role in the science at this point in time as far as the science is concerned. I think that eventually we will have to have more of a role than that because we are the group that can regulate. I think we're the only group that regulates the Greenhouse gases. Maybe the exception is carbon dioxide, although I may need help with who does regulate carbon dioxide. I don't know—

Mr. SCHEUER. Well, let me ask you, the Science Advisory Board has suggested a ten-year research program on just this Greenhouse—

Dr. NEWILL. Oh, yes.

Mr. SCHEUER.—that you're talking about, and it has suggested that EPA call in scientists from the outside to help prepare the plan and to help review the plan.

Dr. NEWILL. Yes.

Mr. SCHEUER. What is your response to that?

Dr. NEWILL. We actually have that underway at the present time. The scientists have been called together, and if I remember correctly—

Mr. SCHEUER. They're working on a plan?

Dr. NEWILL. They're working on a plan. I believe that plan should be completed by August of 1988.

Mr. SCHEUER. Very encouraging. I'm delighted to hear that.

There's been a big preoccupation at EPA with funding the acid rain research and some of us have suggested rather unkindly, I'm sure, that funding this extraordinary level of acid rain research relative to your other research programs is sort of a substitute for doing something about acid rain. The underlying philosophy being that—I guess the underlying rationale being, if you can research long enough, you won't have to do anything about it.

Now, in terms of some rational relationship between your—the levels of funding for your research programs, would you consider shifting funds from acid rain, which has really been researched into the ground, to the global warming problem, especially since the acid rain research supporting the 1990 assessment seems to be about to wind down?

Mr. BRETTHAUER. If I might, I'd like to answer.

Mr. SCHEUER. By all means.

Mr. BRETTHAUER. We believe that the long term acid deposition program, the NAPAP program, has provided definite results, and definite results as far as considering legislation.

Mr. SCHEUER. What do the results of that acid rain research program indicate that our country needs in terms of legislation and remedial programs?

Mr. BRETTHAUER. In terms of remedial programs I think the—

Mr. SCHEUER. In terms of legislation. What does it indicate we ought to have in the way of legislation?

Mr. BRETTHAUER. I think the role of ozone, the role of ozone in acid deposition effects, especially in regard to forests, has been misunderstood. We believe it hasn't been well interpreted in regard to what those would be vis-a-vis acid deposition.

We also believe that the understanding of the degree of acid deposition, especially insofar as it affects various portions of the country is important and was not as well understood as it is at the present time.

I think there are a whole raft of research results that are certainly important in terms of acid deposition, as well as our other ecological monitoring work. We have a—our final work in regard to the 1990 NAPAP assessment, which we hope to lay out all the progress in acid deposition, the research that has been done. Now we plan a orderly transition of that ecological work to other components, especially in regard to global climate and long-term ecological monitoring.

We believe that post acid deposition we will need some type of an assessment program to look at the effectiveness of whatever control measures are provided, if any, the efficacy of controls. We believe that we need to insert some type of an ecological monitoring program for other purposes as well, global climate, stratospheric ozone, and other ecological problems that seem to be emerging.

We see an establishment of a longer term ecological monitoring program as a vital next step in the acid deposition follow-on.

Mr. SCHEUER. How about on funding? After 1989—well, let's say—1989 is likely to be the last year for funding research that can be folded into the final assessment due from the National—from NAPAP, the National Acid Precipitation Assessment Program.

Has EPA determined the kind and the level of funding for acid rain research after 1989?

Mr. BRETTHAUER. We are having intensive discussions at this time on the degree of funding for the acid deposition monitoring—acid deposition program post the 90 assessment. There will be some funding that's necessary, especially in regard to not only putting in place some type of monitoring program to determine whether acid deposition is increasing, decreasing or whatever, but also to answer some questions that are bound to remain after the 90 assessment.

We expect a significant reduction in the acid deposition budget plan. At least the discussions are moving at this time that those funds will be looked at in terms of moving on into global climate and other ecological—other ecological concerns.

Mr. SCHEUER. All right. Let's talk about infrastructure: equipment, facilities and so forth. The Science Advisory Board notes that EPA's infrastructure, laboratory, equipment, facilities, continue to deteriorate, and they cite the example of EPA's Cincinnati Lab, which lacks the instrumentation to identify potentially hazardous materials resulting from byproducts of disinfectant technology, and the Board, the Science Advisory Board recommends that EPA should prepare a report on its needs for improved facilities and equipment.

Has anything like that been contemplated?

Dr. NEWILL. I don't think that we've contemplated really putting together that kind of report.

Mr. SCHEUER. But have you evaluated the need—

Dr. NEWILL. Yes. That's what I'd like to talk to you about.

Mr. SCHEUER. Evaluated the adequacy and the condition of your scientific infrastructure?

Dr. NEWILL. Sure.

Really, in past years, ORD did lack the management processes to assess this kind of thing, but in the 1988 budget year, which would be back in, oh, I guess, 1986, this kind of assessment was actually carried out, and it demonstrated that we did have a tremendous number of needs in this particular area.

Mr. SCHEUER. But you did—

Dr. NEWILL. We did.

Mr. SCHEUER. Yes.

Dr. NEWILL. Yes.

Mr. SCHEUER. So you agree with the assessment of your scientific—

Dr. NEWILL. Agree with the assessment, yes.

And so we started to work on it at that particular time. Since then, in the fiscal year 1988 budget, there was $2 million in funding for equipment replacement from programmatic funds. There has been construction of several new facilities. The field stations at Newport, Oregon and the Edison facility. There's been design for the Chapel Hill, North Carolina Clinical facility. There is now the plans for the biotech facility at Gulf Breeze, Florida.

In addition, the Senate Appropriations Committee report did permit us to buy Government-furnished equipment directly off the GSA Schedule which will enable us to use our monies much more efficiently. So, we have developed a capital equipment acquisition and replacement system that will ensure that we use our enhanced resources more wisely. So there is a management system that is in place.

Mr. SCHEUER. Yes.

Do you have a written appraisal of the need for new scientific—improved scientific facilities and equipment?

Dr. NEWILL. Well, it's the kind of review that we do internally when we're putting our budget together. It's not a written report that I can bring over and hand to you.

Mr. SCHEUER. Yes. Well, I think it would be very helpful if you put those analyses and those assessments in writing.

We have a problem with OMB. They keep blocking our request. We like to indicate to them that EPA itself, as well as its Science Advisory Board, as well as outside experts, feel the need for a significant amount of improving, renovation, rehabilitation, new equipment and new facilities. Modernization of the whole effort—

Dr. NEWILL. We agree that we needed this, but there has been significant progress actually just in the last two budgets, fiscal year 1988 and now our request for fiscal year 1989.

This doesn't mean that every piece of equipment that every laboratory would like to have is there, but the piece of equipment that they are talking about in Cincinnati is on the list. It has a very high priority and, undoubtedly, will be—

Mr. SCHEUER. On the list?

Dr. NEWILL. Yes.

Mr. SCHEUER. Do you have a list of improvements you'd like to make?

Dr. NEWILL. We have a capital equipment list.

Mr. SCHEUER. Does that include facilities, or is that just—

Dr. NEWILL. No, the facilities list is separate from the equipment list.

Mr. SCHEUER. Do you have a facilities list, too?

Dr. NEWILL. Yes. We have two kinds of facilities lists for our own internal use, the new facilities that we would like to have and also we keep a list of repairs that we need to carry out on facilities and that sort of thing.

Mr. SCHEUER. I think both of those are very important and I would very much like for you to provide the Committee with those two lists pertaining to facilities and the list of new equipment that you feel is needed.

Dr. NEWILL. We'll do so.

Mr. SCHEUER. Do you agree in general with the Science Advisory Board's rather negative assessment of your present—of the present state of your facilities and equipment and that they need significant upgrading?

Dr. NEWILL. I think that there has been significant upgrading in the last two years, so that I think things are in much better shape now than they were when I first came to EPA.

That has nothing to do with my being here, but just in the period that I've been able to observe it, so that I think that this is turning around at the present time. But certainly there is room for improvement.

Mr. SCHEUER. Well, good. That's a frank and forthright statement. If we've agreed that you're going to give us a current appraisal of the need for new equipment and the need for improved facilities of the two kinds that you discussed, I think we've accomplished something at this hearing. Don't you agree?

Dr. NEWILL. Yes, we agree.

Mr. SCHEUER. All right. Let me ask you, on the level of research funding, can you tell us what level of research funding EPA requested from OMB for EPA research?

[Pause.]

Mr. SCHEUER. If you don't have that clearly in mind, you could submit that to us also.

Dr. NEWILL. I will submit that to you.

Mr. SCHEUER. That's fine.

[Information to be furnished follows:]

03-Jun-88

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH & DEVELOPMENT

Program Summary Comparison
FY 1989 OMB Submission . FY 1989 Presidents Budget
Total FTE

Program Category--> / MEDIUM	Scientific Assessment	Technical Information & Liaison	Monitoring Systems & QA	Health Effects	Env. Engineering & Technology	Env. Processes & Effects	Characterization & Fate	Great Lakes	Exploratory Core Prog.	Stratospheric Modification	Acid Deposition	Program Management & Support	Reimbursable Positions	MEDIUM TOTAL
AIR														
'89 OMB Sub Bud.	54.8		117.6	125.9	61.7	14.3	60.0			18.0				482.3
'89 Pres. Bud.	53.4		115.1	122.6	58.7	14.1	57.5			14.0				435.4
Delta	-1.4		-2.5	-3.3	-3.0	-0.2	-2.5			-4.0				-46.9
WATER QUALITY														
'89 OMB Sub Bud.	9.5		48.4	28.6	42.1	189.5		8.0						326.1
'89 Pres. Bud.	5.5		46.3	26.7	37.7	184.9		8.0						279.1
Delta	-4.0		-2.1	-1.9	-4.4	-4.6		0.0						-47.0
DRINKING WATER														
'89 OMB Sub Bud.	9.0		29.3	48.2	40.3	27.6								194.4
'89 Pres. Bud.	9.0		28.7	46.4	39.3	39.1								192.8
Delta	0.0		-0.6	-1.8	-1.0	1.5								-1.9
HAZARDOUS WASTE														
'89 OMB Sub Bud.	23.2		48.7	12.0	84.8	54.9								220.2
'89 Pres. Bud.	23.1		47.8	12.0	84.8	55.1								222.8
Delta	-0.1		-1.1	0.0	0.0	0.4								2.6
PESTICIDES														
'89 OMB Sub Bud.	6.7		7.1	40.5	3.0	69.3								126.6
'89 Pres. Bud.	6.7		7.3	38.1	3.0	61.2								116.3
Delta	0.0		0.2	-2.4	0.0	-8.1								-10.3
RADIATION														
'89 OMB Sub Bud.			48.7		18.0									83.7
'89 Pres. Bud.			4.7		18.0									22.7
Delta			-41.0		0.0									-61.0
INTERDISCIPLINARY														
'89 OMB Sub Bud.	24.8	43.8	14.5						9.3					92.1
'89 Pres. Bud.	24.1	43.1	14.5						9.3					91.0
Delta	-0.4	-0.7	0.0						0.0					-1.1
TOXIC SUBSTANCES														
'89 OMB Sub Bud.	8.0		27.9	62.6	15.6	89.0								300.1
'89 Pres. Bud.	4.0		25.2	60.6	11.0	87.8								188.3
Delta	-4.0		-2.7	-2.0	-4.6	-1.2								-11.8
MULTI-MEDIA ENERGY														
'89 OMB Sub Bud.					18.7						60.8			79.5
'89 Pres. Bud.					20.0						59.1			79.1
Delta					1.3						-1.7			-0.4
MANAGEMENT & SUPPORT														
'89 OMB Sub Bud.												105.5		105.5
'89 Pres. Bud.												24.5		24.5
Delta												-81.0		-81.0
SUPERFUND														
'89 OMB Sub Bud.	18.4	1.0	28.3	6.0	51.9	14.0			1.0					120.6
'89 Pres. Bud.	14.6	1.0	25.3	3.0	47.9	10.9			1.0					103.8
Delta	-3.8	0.0	-3.0	-3.0	-4.0	-4.0			0.0					-17.8
LUST TRUST FUND														
'89 OMB Sub Bud.					3.0									3.0
'89 Pres. Bud.					2.0									2.0
Delta					-1.0									-1.0
REIMBURSE POSITIONS														
'89 OMB Sub Bud.													0.0	0.0
'89 Pres. Bud.													41.0	41.0
Delta													41.0	41.0
GRAND TOTAL														
'89 OMB Sub Bud.	181.1	44.8	384.5	343.8	389.1	458.4	60.0	8.0	10.3	18.0	60.8	105.5	0.0	1974.1
'89 Pres. Bud.	140.4	44.1	314.9	329.4	342.4	411.2	57.5	8.0	10.3	14.0	59.1	24.5	41.0	1897.3
Delta	-10.7	-0.7	-69.6	-14.4	-16.7	-47.2	-2.5	0.0	0.0	-4.0	-1.7	-81.0	41.0	-136.8

03-Jun-88

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH & DEVELOPMENT

Program Category Comparison
FY 1989 OMB Submittal vs. FY 1989 Presidents Budget
TOTAL DOLLARS

Program Category--> MEDIUM	Scientific Assessment	Technical Information & Liaison	Monitoring Systems & QA	Health Effects	Env. Engineering & Technology	Env. Processes & Effects	Chemical Trans & Fate	Great Lakes	Exploratory Core Prog.	Stratospheric Mod	Acid Deposition	Program Management & Support	Reimbursable Positions	MEDIUM TOTAL
AIR														
'89 OMB Sub Bud.	3734.3		8323.3	12841.8	3881.5	1766.6	[illegible]			4669.7				43814.6
'89 Pres. Bud.	4969.9		14746.8	21102.3	6399.2	2224.1	[illegible]			11829.3				72498.3
Delta	2238.6		6423.5	8260.5	2517.7	457.5	[illegible]			5159.6				28681.7
WATER QUALITY														
'89 OMB Sub Bud.	1495.7		2108.0	1129.0	5331.4	4288.6	[illegible]		2497.6					19947.1
'89 Pres. Bud.	647.9		3456.3	1496.6	5666.0	11671.3	[illegible]		1959.1					25097.1
Delta	-847.8		1348.3	367.6	334.6	7382.8	[illegible]		461.5					9150.0
DRINKING WATER														
'89 OMB Sub Bud.	296.8		1277.3	8321.9	2276.6	3436.1	[illegible]							12996.7
'89 Pres. Bud.	728.9		2955.6	8074.9	5179.6	5058.8	[illegible]							21997.8
Delta	432.1		1678.3	2753.0	2903.0	1636.7	[illegible]							9401.1
HAZARDOUS WASTE														
'89 OMB Sub Bud.	2740.4		9181.5	1483.4	11428.8	5397.6	[illegible]							30428.7
'89 Pres. Bud.	3748.6		13387.1	1647.3	14822.4	7783.7	[illegible]							41339.1
Delta	1008.2		4178.6	-36.1	3394.6	2386.1	[illegible]		0.0					10910.4
PESTICIDES														
'89 OMB Sub Bud.	343.6		1040.9	1962.2	2281.1	3153.9	[illegible]							8781.7
'89 Pres. Bud.	773.1		1382.1	3837.0	2274.4	6158.4	[illegible]							14425.0
Delta	429.5		341.2	1874.8	-6.7	3004.5	[illegible]							5643.3
RADIATION														
'89 OMB Sub Bud.			0.0		2300.0		[illegible]							2300.0
'89 Pres. Bud.			167.9		3858.3		[illegible]							4026.2
Delta			167.9		1558.3		[illegible]							1726.2
INTERDISCIPLINARY														
'89 OMB Sub Bud.	898.3	670.4	888.4	0.0			[illegible]		15663.4					18107.5
'89 Pres. Bud.	2245.4	4161.8	1708.8	10000.0			[illegible]		16034.2					34147.2
Delta	1347.1	3491.4	820.4	10000.0			[illegible]		380.8					16039.7
TOXIC SUBSTANCES														
'89 OMB Sub Bud.	296.2		4614.3	7310.1	3238.1	4207.9	[illegible]							19663.6
'89 Pres. Bud.	427.3		4983.2	9113.2	2337.2	9776.3	[illegible]							26609.2
Delta	131.1		368.9	1808.1	-897.9	5568.4	[illegible]							6945.6
MULTI-MEDIA ENERGY														
'89 OMB Sub Bud.					2433.4	[illegible]	[illegible]				50745.8			53179.2
'89 Pres. Bud.					3466.7	[illegible]	[illegible]				51990.8			55457.5
Delta					1033.3	[illegible]	[illegible]				1245.0			2278.3
MANAGEMENT & SUPPORT														
'89 OMB Sub Bud.							[illegible]					0.0		0.0
'89 Pres. Bud.							[illegible]					11839.4		11839.4
Delta							[illegible]					11839.4		11839.4
SUPERFUND														
'89 OMB Sub Bud.	3209.2	900.0	11893.0	3350.0	26629.6	5189.1	[illegible]		7300.0			0.0		58272.9
'89 Pres. Bud.	4488.7	625.8	13031.4	3745.0	32398.5	4727.9	[illegible]		7850.0			250.0		66817.3
Delta	1279.5	125.8	1138.4	395.0	3768.9	-461.2	[illegible]		50.0			250.0		8544.4
LUST TRUST FUND														
'89 OMB Sub Bud.					1200.0		[illegible]							1200.0
'89 Pres. Bud.					770.0		[illegible]							770.0
Delta					-430.0		[illegible]							-430.0
REIMBURSE POSITIONS														
'89 OMB Sub Bud.							[illegible]							0.0
'89 Pres. Bud.							[illegible]							0.0
Delta							[illegible]							0.0
GRAND TOTAL														
'89 OMB Sub Bud.	12014.5	1570.4	39295.7	33898.4	60994.5	27826.0	7899.2	1497..	23183.4	4669.7	50745.8	0.0		264296.8
'89 Pres. Bud.	18029.8	4787.6	59736.2	59218.3	77172.3	47388.4	11226.7	1959.1	23884.2	11829.3	51990.8	12089.4	0.0	378024.1
Delta	6015.3	3217.2	20440.5	25319.9	16177.8	[illegible]	3327.5	461.5	700.8	5159.6	1245.0	12089.4	0.0	113730.1

Mr. SCHEUER. And then you might indicate, along with the levels of funding that you requested and the items for which you requested it, which of those specific items did not receive funding from the Administration, were turned down by OMB. That would be, more or less, taking those two things together. That would be a sort of an agenda of things that are needed in the future, wouldn't it?

Dr. NEWILL. You're talking now about facilities?

Mr. SCHEUER. Facilities and equipment.

Dr. NEWILL. Okay.

Mr. SCHEUER. For research.

As I mentioned, over the last seven, seven and a half years, resources for EPA's research have been declining significantly in real terms and I said if you take out those two programs where there's been a significant increase, for all of the rest of the programs the production has been about 50 percent in real terms, which should—I'm sure that's of concern to you.

The number of personnel involved in EPA research has gone down 20-odd percent. Certainly 20 percent.

What would you say, what kind of an appraisal would you make of the effect of this decline, both in funding and in personnel, on EPA's ability to conduct high-quality environmental research?

Dr. NEWILL. I think I said once before to you that I do not believe that that changes the quality of the research, as such.

Mr. SCHEUER. You mean the quality of the research—

Dr. NEWILL. It changes the quantity of research.

Mr. SCHEUER.—that you are able to do; right.

Dr. NEWILL. Yes.

Mr. SCHEUER. Well, that's fair.

Dr. NEWILL. But I would like to answer—supply an answer for your question of another kind. I'd like to go back to my two-hat situation and talk to you first as a manager.

As you know, there is an agreement between the White House and the Congress on spending limits. Those spending limits were translated into guidance for fiscal year 1989, a proposal that is with the Congress for consideration at the present time. That program, that we've proposed, I believe is a reasonable level of research for most important environmental problems of regulatory concern.

It does not address all problems where research is desirable, and it does not address developing a long-term research program. And both the Administrator and I are particularly concerned about the long-term research program, and you've already mentioned the Alm Committee which is looking at that specifically.

But I'd like to put on my scientist hat for a minute. I've had more than 30 years of experience in this particular field and I really believe we do not have the dollars to meet the goals in authorization, and I really think that either the goals must be altered or there must be more resources.

Mr. SCHEUER. The goals must be altered?

Dr. NEWILL. Or must be more resources.

Mr. SCHEUER. Yes. Well, it's obvious that we feel there must be more resources.

How would you alter the cloth to fit the—how could you alter your goals?

Dr. NEWILL. I can't alter my goals.

Mr. SCHEUER. Can't alter your goals? Then there must be more resources.

Dr. NEWILL. Let me say it another way. We'll be glad to work with you to try to decide what changes should be made.

Mr. SCHEUER. Well, you couldn't—no one could ask for more a forthright—forthcoming statement, and frankly, that has typified our relationship with you. You've always been forthright and forthcoming and these problems that we're addressing, I am sure, are neither of your making or to your liking, and I—it's embarrassing me, too, to engage in asking these tough questions from a guy whose heart would—a guy who would like to see a different situation.

I really feel very awkward about pinning you down on these things. God is coming to your relief.

[Laughter.]

Mr. SCHEUER. We just had a roll call vote.

I'll defer the relief temporarily. It's only a quorum call and I'll skip this quorum call so we can continue with our colloquy.

But you know, going—I mean, it's painful for me to hear you say, we have a set of goals, we have some funding but the funding doesn't make the goals possible of achievement and we can't alter our goals. Of course we can't alter our goals.

Where does that leave us? We're engaged in a binge of spending. We're buying bigger and heavier cars they call the gas guzzlers—an orgy of spending on cars and homes that we really can't afford. We have $160 billion budget deficit that we're meeting by borrowing from abroad, and how long our people abroad are going to continue to accept our market is anybody's guess.

So we're engaged in this splurge of consumer spending while we're cutting down scientific research that has always been the keystone to our national greatness.

It's just painful for me to hear you say what you say and feel that that is the appalling set of priorities that we've established in this country that are seriously jeopardizing the future.

I feel for you. I'm sure you're as embarrassed at this situation as I am. I don't want to put words in your mouth.

You've been a very forthcoming and cooperative witness. I appreciate your attitude; I appreciate the help you've given us, really, since you've been in your position.

We'll be very happy to receive the reports that you indicated you'll be sending us and we'll be discussing with you, informally, I hope, how we find a way out.

Is there anything that can be done in the next seven and a half or eight months remaining in this Administration, or must we, in this area, as in some of the other areas of our national life—are the appalling condition of our national education system—do we have to wait to bring out science and technology research establishment up to credible standards until a new administration comes in? I hope not.

I hope that even in the waning last eight months of this Administration we can begin together to make some plans for the future.

I appreciate your testimony very much. Thank you.

Dr. NEWILL. Thank you.

Mr. SCHEUER. All right. We'll invite Dr. Morton Lippmann of the Institute of Environmental Medicine at NYU and a member of the EPA Science Advisory Board to take the chair.

We're very happy to have you with us, Dr. Lippman.

Dr. LIPPMANN. Thank you, Mr. Chairman.

Mr. SCHEUER. Just take such time as you may need, 10, 12, 15 minutes, and let us know of your thinking.

Dr. LIPPMANN. You, Mr. Chairman, have made my remarks shorter because you've covered in eloquent detail many of the points that were in the SAB report, in the report on the EPA grant program.

Let me just give you a little bit of the background I bring here. I've been on the Science Advisory Board's Executive Committee since 1983. I've been working on the Clean Air Scientific Advisory Committee since 1980, and was chairman for years until October. I currently chair the External Advisory Committee on Indoor Air and Radon. I happen to be a member of the Alm Committees. And I've served on the review panels for the EPA extramural grants and been a grantee three times.

If you have any further questions in that area, perhaps I can be of help.

My testimony is essentially that of the SAB Committee on the Budget, which has been submitted and I'm here to perhaps amplify on a few points and be available for any questions you have about our collective report.

As I was listening to your opening statement and thinking about it, perhaps I can give a good code word or title for what's needed in EPA, which goes a little bit beyond our written report.

Mr. Ruckelshaus firmly established the concepts of risk assessment and risk management being overlapping, but essentially, somewhat separable activities of EPA. What's missing is risk anticipation, and I think this perhaps might be a way of organizing a number of the thoughts that have been expressed into a programmatic theme for EPA.

EPA hasn't been very good, as you have identified, seeing what's coming down the road, and that will continue to be a real problem to the agency.

As you've noted, the SAB Committee and the grantees who have submitted good grants which haven't been funded, have—

Mr. SCHEUER. Good grant applications?

Dr. LIPPMANN. Good grant applications; addressing some of these things, like the stratospheric ozone and the global climate and some of these things which EPA, because of its regulatory responsibilities, wants to get to but doesn't give a very high priority until the problem is on top of them.

The only other thing I think I need to amplify—well, two things.

One, is the budget looks—is really worse, in my view, than even you have painted, plus a lot of what is called research and spent with ORD dollars is not as much research as it used to be. For instance—

Mr. SCHEUER. What is it?

Dr. LIPPMANN. Well, in terms of indoor air pollutants, which we're quite familiar with, most of the dollars are going to what's called, frankly, risk communications, trying to tell the public what

they need to know without having the research base to really be able to know what they need to know. The same thing is on the air toxics program. Our Committee concluded that there aren't anywhere near enough resources to do a serious job of assessing exposure for the real effects side of the air toxics issue, and so, we agreed that under the current circumstances the emphasis on risk assessment is appropriate.

That means, trying to make the best you can with inadequate knowledge and research.

So, aside from whole programmatic areas taking up what used to be research dollars, important things like risk communications are taking up research dollars. So that's one issue.

The other is the internal staff. It's aging. There has been no opportunity for new hires with reduction in force, and so, as we've addressed in our report, we are concerned about making good use of what have now become middle level people in the agency, at the same time recognizing that the new blood, the new ideas, the new enthusiasm that normally occur in a program by new hires is not there, as well as new skills. That is, these new issues may need a different skill mix than the people that you've got left and you're got to reassign to the—

Mr. SCHEUER. Has anybody done a study, even a brief analysis, of the new skill mix that is needed to face up to these many new environmental problems that we've just become aware of?

Dr. LIPPMANN. We raise that explicitly in very general terms in this SAB report. Frankly—

Mr. SCHEUER. What skills are not residing in EPA now ought to be represented?

Dr. LIPPMANN. For instance, the stratospheric ozone and global climate raise a whole different class of issues, geochemistry, geophysics, need to be there, and I haven't got a fully considered answer and I hate to do it solo, my expertise had to do with a somewhat limited part of the whole EPA mission, which is of course is very broad, but I think it is clear and we explicitly stated the problem of skills needed.

Mr. SCHEUER. Well, do you think you and your colleagues on the Science Advisory Board could give a report to this Committee and to your agency as to your judgment as to the kinds of new skills that they should be working hard to acquire?

Dr. LIPPMANN. The executive committee is meeting next week, and I can bring your request back to them and try to get a resolution and a response.

Mr. SCHEUER. I'd appreciate that very much.

Dr. LIPPMANN. One other thought. I think I'd like to take a couple of minutes of your time to mention the importance of the old problems. Perhaps I am especially sensitive to old problems like criteria air pollutants, having served so long on the Clean Air Scientific Advisory Committee, but we are dealing with reissuing standards for ozone, dealing with the need for a new standard on acid aerosols that we breathe and that are having health effects, and at the same time the budget for research on the criteria pollutants has been going down. The EPA was not able to respond to the mandate of Congress in the 1977 Clean Air Act authorization and revision that it either set a short term standard for NO2 or the

Congress demanded that EPA either set a short term standard for NO2 or tell why they wouldn't be able to do so. They have really done neither.

The issue of chronic effects of ozone, perhaps one of the major problems affecting the whole population, there has been no research in the agency. I am not blaming Dr. Newill or Dr. Goldstein, who preceded him. Those have been the imperatives but the old problems which are getting less research attention are as great or greater than they were and are not the latest thing so they don't get—they're not the squeaky wheel that gets the dollars.

I think obviously I could bring out many more things here in areas that are not my own pet hobbyhorses, the issues like waste incineration, land disposal. These aren't going away either and a crisis is coming upon us. The EPA is doing the best it can in a limited way but it is not really taking on those issues the way they need to be taken on.

Now I am going from global to the garbage and the air we breathe. These are the problems that there's just far too little attention given to.

Mr. SCHEUER. The Science Advisory Board made a number of recommendations for increased research funding. If Congress was going to allocate another $10 to $20 million dollars, what kind of priority order would you place the programs in that you'd like to see addressed?

Dr. LIPPMANN. I guess the thing that's most efficient is the extramural grants program, to bring not only participatory ideas forward and to establish a liaison with the academic community, get them involved. That's not much. Dr. Newill, based on this work which he agrees with essentially, is talking about $100 million, and that is the order that is needed. The Agency is using its band-aids reasonably well with the funds it has to cover the issues that it is forced to address. I think the thing that they are not doing at all is supporting the kind of research which will be anticipatory.

Mr. SCHEUER. Can you tell us which of the anticipatory research programs you think are in most urgent need of funding. Can you give us a couple of for instances?

Dr. LIPPMANN. Well, frankly, there is no anticipatory program at all right now. What I am talking about is not in programmatic areas but in the area of investigator- initiated proposals, which will create the database which will tell us what needs are going to emerge. If they had already emerged, I could tell you, but I think the main fault is in the lack of looking for what's coming over the hill that they haven't been confronted with.

Mr. SCHEUER. Well, Dr. Lippmann, you've been very helpful, very forthcoming. I have to go over to the Floor now, because in another minute or two there will be a five-minute roll call vote. If I'm not well on my way over there, the voters of my district will be very angry at me for missing it.

So, thank you very, very much for appearing here today. We very much appreciate your testimony.

Now this last panel, composed of Dr. William Bishop, Dr. William Adams, and Dr. Richard Luthy, if I can ask your indulgence, you'll know when the bells ring, and I'll be back in less than 10 minutes after that.

We will suspend the hearing for about 15 minutes.

[Brief recess.]

Mr. SCHEUER. That roll call vote didn't come, and it is about 20 or 25 minutes away. Are there just the two of you, Dr. Bishop and Dr.—I'm expecting Dr. Bishop, Dr. Adams and Dr. Luthy. Here we are.

We are going to have a whole series of roll call votes on the Trade Bill and it will come in about 20 minutes or maybe 25 minutes, so what I'd like to do is rather than ask you to stay here, what I'd like to do is get your affirmative testimony on the record and then if we get cut off during the questions, I can always submit them by mail and not ask you to hang around for maybe half an hour to an hour while I wait there for a series of roll call votes.

Is that okay? All right. We have Drs. Bishop, Adams and Luthy. All of your prepared remarks will be printed in full at this point in the record, so why don't I call on each of you to speak for about five minutes, then we'll get all the affirmative testimony out of the way before the roll call vote starts so you won't have to hang around here. Then after that I'll have some questions for whatever time remains.

So let's start out with Dr. William Bishop.

STATEMENT OF DR. WILLIAM E. BISHOP, PRESIDENT, SOCIETY FOR ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY; ACCOMPANIED BY DR. WILLIAM J. ADAMS, SOCIETY OF ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY AND DR. RICHARD G. LUTHY, PRESIDENT, ASSOCIATION OF ENVIRONMENTAL ENGINEERING PROFESSORS

Dr. BISHOP. Thank you, Mr. Chairman. I am Dr. William Bishop, President of the Society of Environmental Toxicology and Chemistry [SETAC). I would also like to introduce Dr. William J. Adams, who is the chairman of our Society's Government Affairs Committee.

Mr. SCHEUER. Let me interrupt you. We are running very short of time, so I would like us all to drop the ceremonials and get right to the substance, okay? And that way we'll use our limited time to best advantage, and it would be much better if you just talked at us, didn't read, and don't hesitate to refer to anything that you have heard this morning from the other witnesses who testified in the first panel. Okay? Thank you, Dr. Bishop.

Dr. BISHOP. In August of 1987, the Society, clearly recognizing the need to improve our ability to conduct environmental risk assessment, conducted a workshop entitled Consensus Research Needs and Priorities in Environmental Risk Assessment. That report, which we have shared with the Committee and was published earlier this year, presents the consensus recommendations of more than 40 scientific experts that participated in that five-day workshop. I believe that that report also reflects the best judgment of the scientific community at large. It has been widely reviewed with and was concurred in principle to by a number of other professional and trade associations, which would include the Science Advisory Board of EPA, the American Chemical Society, National

Wildlife Federation, and the National Agricultural Chemicals Association.

We would concur with the recent statements by Mr. Thomas, the EPA Administrator, that while in many cases our abilities to conduct quantitative scientific data based health assessments have progressed exponentially during the life of the EPA, our ability to do so with regard to ecological systems lags significantly behind.

Dr. Adams will describe in a little more detail why we believe that the research programs outlined in the workshop report represent the basic framework for research under which this new initiative should be conducted, a new national research initiative which is built upon but which exceeds and enhances the currently existing research activities is what we feel is needed to ensure that the scientific progress necessary to enable us to conduct valid ecological risk assessments is developed.

[The prepared statement of Dr. William E. Bishop follows:]

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draft; (3 pages)

SOCIETY OF ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY

April 14, 1988

Representative James H. Scheuer, Chairman
Subcommittee on Natural Resources,
Agriculture Research, and Environment
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Scheuer:

On behalf of the Society of Environmental Toxicology and Chemistry (SETAC) we wish to notify you that we accept your offer to testify at the Natural Resources, Agriculture Research, and Environment Subcommittee hearing on the 1989 fiscal year budget request for EPA environmental research, demonstration, and development activities. SETAC will be represented by the President of the Society (William E. Bishop) and the Government Affairs Chairman (William J. Adams). Our society has had close ties with many of the EPA programs and we are pleased to have this opportunity to comment on the subject of environmental risk assessment.

SETAC sponsored a workshop in August of 1987 to address the issue of what are the research priorities in environmental risk assessment. We will verbally communicate the results to you at the hearing. The key points of interest from the workshop include the following:

1. Environmental risk assessment is a scientific technique of evaluating the the uncertainty associated with knowledge about environmental effects and exposure and estimates the probability that an identified problem will actually occur or has occurred in the environment as a result of man's activities or natural events.

2. Environmental risk assessment can be a powerful tool for solving environmental problems and reducing the uncertainty associated with making environmental management decisions and allocating resources. Limitations associated with environmental risk assessment result from a fundamental lack of knowledge in

certain areas. Four key areas recognized as needing substantial research to improve the risk assessment process were identified:

a. Risk assessment methodology
b. Aquatic toxicology
c. Terrestrial toxicology and
d. Chemistry, fate and modeling

3. Environmental risk assessment procedures are directly applicable and can greatly aid in the decisions that will be made on critical national issues including ecological impacts of improper disposal of hazardous wastes, contamination of groundwater and surface water, potential impacts of releases of genetically engineered organisms, effects of industrial and municipal effluents on aquatic ecosystems, air pollution's impacts on forests and destruction of wetland ecosystems.

4. The current level of funding in the area of environmental risk assessment is too low to achieve the rapid scientific advancement in the state of the art that is needed to deal with critical national issues. To effectively acquire the information that is needed a major research program, similar in magnitude to the Acid Rain Program is needed. SETAC recommends a $75 million dollar per year initiative for 10 years.

We are looking forward to discussing this subject matter with you at the hearing. Additional details are provided for your review and for the written record.

William E Bishop

William E. Bishop, President
Society of Environmental
Toxicology and Chemistry

William J. Adams

William J. Adams, Chairman
Government Affairs Committee
SETAC

WORKSHOP REPORT
SOCIETY OF ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY

Research Priorities in Environmental Risk Assessment

August 16-21, 1987
Breckenridge, Colorado

Edited by:
James A. Fava
William J. Adams
Robert J. Larson
Gary W. Dickson
Kenneth L. Dickson
William E. Bishop

Sponsored by:
U.S. Army Medical Research and Development Command
U.S. Army Chemical Research Development and Engineering Center
The Procter and Gamble Company
The National Agricultural Chemicals Association
Dow Chemical Company
U.S. Environmental Protection Agency

To: Dr. Kenneth L. Dickson
President, Society of Environmental Toxicology and Chemistry

It is our pleasure to submit to you this report, "Research Priorities in Environmental Risk Assessment." In accordance with SETAC's goal of providing a forum for communication among professionals involved with the use, protection, and management of the environment, the Society's Technical and Governmental Affairs Committees organized a workshop, "Consensus Research Needs and Priorities in Environmental Risk Assessment" to identify the research needed to enhance capabilities for conducting environmental risk assessments.

We believe that local, national, and global environmental problems can best be addressed by utilizing the environmental risk assessment approach. The research program outlined in this report will significantly enhance the scientific foundation of the risk assessment process, making it possible to establish environmental priorities on the basis of comparative risk and to allocate limited resources to address the problems of greatest risk.

This report represents the consensus recommendation of more than 40 experts from a wide variety of disciplines representing a cross-section of the Society membership—academia, governmental agencies, public-interest groups, and industry. We therefore believe that this report reflects the best judgment of the scientific community at large. As such, it provides the basis for planning, budgeting, and expanding an initiative for environmental risk assessment research during the next several years.

We are pleased to acknowledge the significant efforts of the many workshop participants who contributed to the development of this report. Thanks are also due to the governmental agencies, associations, and industrial organizations that generously supported the workshop. In addition, we are grateful to Marveen Fishman and Julie Rieser of Battelle Columbus Division and Martina Bianchini of the Monsanto Company for their excellent logistical support, and to Karl Nehring of Battelle Columbus Division for his outstanding editorial assistance.

On behalf of the workshop participants, we hope that this report will be useful in guiding environmental risk assessment research during the next decade.

Respectfully submitted,

William J. Adams
Chair, Governmental Affairs Committee

James A. Fava
Chair, Technical Committee

EXECUTIVE SUMMARY

RESEARCH PRIORITIES IN ENVIRONMENTAL RISK ASSESSMENT--A SETAC WORKSHOP

Nature and Scope

The environmental issues facing society today are the most critical in our nation's history. Difficult decisions must be made about potentially expensive solutions to environmental problems. Environmental risk assessment will provide the information necessary to ensure that the best decisions are made. Environmental risk assessment is the most efficient, technically sound, and cost-effective approach to providing the information required to make these decisions. However, research is urgently needed to enhance the use of environmental risk assessment.

Environmental risk assessment integrates knowledge concerning the possible effects of proposed actions that expose plants, animals, and ecosystems to pollutants or stresses in air, water, and soil. The formal scientific techniques used in risk assessment take into account the uncertainty associated with knowledge about effects on the environment and estimate the probability of an identified risk being realized in the environment as a result of a contemplated action. Risk assessment provides technical input to risk management, the process of making decisions about the acceptability of risks and the need for risk reduction.

The Society of Environmental Toxicology and Chemistry (SETAC) recognizes the value of environmental risk assessment in evaluating the extent and magnitude of environmental problems, maximizing options for solving these problems through early detection, in evaluating the efficacy of alternative remedial actions, and in prioritizing and allocating limited research resources.

As a result of this recognition, SETAC convened a workshop involving 40 scientists representing governmental organizations, universities, public-interest groups, industry, and contract research laboratories to identify the research needed to enhance the development of environmental risk assessment strategies and methods.

Objectives and Context

The charge given to workshop participants was to identify technical research needs that would best improve the use and understanding of environmental risk assessment. Current research programs, while achieving substantial advances in knowledge and understanding, do not adequately address the issues necessary to enhance the use of environmental risk assessment in solving key environmental problems such as:

- ecological impacts of improper disposal of hazardous wastes;
- contamination of groundwater and surface water;
- impacts of genetically-altered organisms on the environment;
- effects of municipal and industrial wastewater effluents on aquatic ecosystems;
- air pollution impacts on forest resources;
- destruction of wetland ecosystems; and
- effects of rapid population growth and population shifts to coastal areas on fisheries, shoreline stability, and other considerations.

Improved risk assessment techniques are important in striking a balance between a commitment to protect and improve the quality of life and economic stability of our nation and a mandate to focus limited pollution-control resources on those problems posing the greatest threat to the environment and to the economy. Striking such a balance also contributes to maintaining and improving our nation's competitiveness in international markets.

Main Findings and Conclusions

Environmental risk assessment is a powerful tool for solving environmental problems and allocating resources. Limitations currently associated with environmental risk assessment result from two factors: (1) fundamental lack

of knowledge in certain areas and (2) a concentration on the use of generalized hazard assessment techniques. Current methods for estimating environmental exposure and effects do not provide the necessary depth of understanding required for risk assessment and ignore the effects of multiple toxicants and the complex dynamics of ecosystem functions. Present understanding of ecosystem structure and function is also inadequate to determine when significant disruption is imminent and what constitutes unacceptable change.

Four key areas are recognized as needing substantial research to improve environmental risk assessment:

1. Risk assessment methodology;
2. Aquatic toxicology;
3. Terrestrial toxicology; and
4. Chemistry, fate, and modeling.

Risk Assessment Methodology

A significant amount of research is needed to validate and improve the risk assessment process itself. Large-scale validation studies using whole ecosystems are envisioned in which laboratory-to-field extrapolations can be verified for a range of chemicals with varying physical, chemical, and toxicological properties in different environments.

For the risk assessment process to work, specific effects endpoints need to be identified. Development of ecologically significant endpoints requires an increased research on the biology, physiology, and ecology of terrestrial and aquatic biota to better interpret the ecological significance of observed changes and predict higher-level effects (e.g., population) from simple toxicological data bases. Environmental exposures need to be better quantified and associated uncertainties identified. Currently there are no generally accepted or commonly used ecological effects models.

Communication of the risk assessment process needs to be improved. The challenge is to reduce complexity to an understandable, informative message for regulators, those regulated, professionals, elected officials, and the general public. The development of expert systems to enhance the data base management and computerized information-processing capabilities needed for risk assessment is also essential.

Aquatic Toxicology

In order to quantify and predict the biological effects resulting from exposure to contaminated sediments, the bioavailability of chemicals adsorbed to sediments and the factors controlling bioavailability must be quantified.

A better understanding of the microbial ecology of aquatic ecosystems is also needed, including an understanding of community interactions and of the regulation and metabolism of bacteria, photosynthetic bacteria, algae, protozoa, and fungi. In addition, increased use of genetically-altered organisms requires greater knowledge of their fate and transport with regard to population dynamics and ecology.

Research should be undertaken to improve aquatic risk assessment procedures by enhancing our knowledge of the biochemical, pharmacological, and toxicological mechanisms of xenobiotic chemicals and chemical mixtures in aquatic organisms. The ability to predict and confirm ecosystem stress from controlled laboratory and field investigations is essential to improving assessment procedures.

Quantitative structure-activity relationships and physiological/pharmacokinetic models need to be extended to allow extrapolation to untested chemicals. Furthermore, identification and measurement of ecosystem stress are hampered by the lack of a basic understanding of how toxicants affect the dynamics of aquatic systems encompassing interspecies interactions, nutrient cycling, decomposition, and energy flow.

Terrestrial Toxicology

A greater understanding of how chemical structure, soil properties, and other factors affect the biotransformation and biological availability of contaminants in the terrestrial environment is essential. Improved methods of measuring the routes of uptake and exposure to plants and animals of chemicals applied to terrestrial ecosystems will significantly improve terrestrial risk assessment methods.

The rational choice of appropriate sentinel species representative of a wide range of plants, animals, and microbes would enable exposure or toxicity to be recognized and would facilitate biological monitoring and assessment of remedial actions. The impact of microorganisms and vegetation on chemical concentrations in soils requires additional investigation to improve the ability to quantitatively estimate exposure concentrations.

At present there is a very limited data base for comparative biochemistry and physiology of most nonmammalian organisms of ecotoxicological concern. Extending this data base will assist in the inevitable need for cross-species extrapolation and will help identify surrogate and sentinel species.

Current field test methodology for evaluating the responses of animal, plant, and microbial populations to xenobiotics is inadequate. Furthermore, there is a need to find reliable alternatives to large-scale field testing.

Laboratory study designs are urgently needed to measure sublethal behavioral effects. Although these effects are difficult to observe in the field under natural conditions, they are important for the survival and productivity of species at all ecosystem levels.

In order to predict ecosystem effects from environmental residues, interactions between the biotic and abiotic components of the ecosystem must be better understood. In addition, ecosystem-level processes such as biogeochemical cycling, photoautotrophy, and resilience need to be more fully elaborated.

Chemistry, Fate, and Modeling

In order to improve the accuracy, speed, and utility of risk assessments, the problems of analysis of complex mixtures must be resolved. Because the behavior of toxic chemicals in the environment is determined in large part by their sorption-desorption mechanisms, knowledge of the kinetics of sorption and desorption is basic to understanding and predicting the effects of these chemicals.

There is a need to quantify the processes controlling the transport and fate of particulate matter (bottom, suspended, biotic, and abiotic) and its role in the transport and fate of toxic chemicals. Mechanisms of deposition and resuspension of particulate matter require additional research.

The major cycling mechanism of carbon in any ecosystem is biodegradation; thus, knowledge of biodegradation kinetics is crucial to the development of effective degradation models needed for risk assessment. Similarly, knowledge of atmospheric transport and fate processes is essential for evaluating human, animal, and plant exposures from chemical deposition. Such knowledge is also necessary for assessing the impact of natural and anthropogenic chemicals such as carbon dioxide and chloro/fluorocarbons on the atmosphere.

Basic techniques need to be developed to track genetic information through various environmental compartments in order to understand the fate and transport of genetically-altered organisms. Field validation of exposure models is also needed to provide evidence that model predictions in various compartments are credible. This research will improve the cost-effectiveness of laboratory testing and the utility of the data produced. Finally, probabilistic exposure models need to be more fully developed, because they form an integral part of risk assessment methodology.

Recommendations

- **A new $75 million per year, 10-year research initiative is needed to ensure the progress required to develop effective environmental risk assessment strategies and methods.**
- **The new research initiative should build upon and enhance relevant existing research activities.**
- **Research fund allocations should be balanced among federal laboratories, universities, and other research organizations.**
- **The primary responsibility for this research lies with the United States Government. The initiative should include the Environmental Protection Agency, the Department of Agriculture, the Department of Health and Human Services, the Department of the Interior, the Department of Commerce, the Department of Defense, and the National Science Foundation.**

1.0 INTRODUCTION

1.1 BACKGROUND

The world faces many critical environmental issues that have an impact on the public welfare, the environment, and the economy. Improper disposal of hazardous wastes, pesticide impacts on terrestrial and aquatic life, forest decline, loss of habitat, consequences of genetically-altered organisms in the environment, contamination of groundwater and surface water, and a host of other issues demand that resources continue to be made available to solve these difficult environmental problems. To minimize the impact on our ecological resources, a research initiative to enhance our ability to develop environmental risk assessments is critically needed.

Environmental risk assessments estimate risks resulting from exposure of plants, animals, and ecosystems to pollutants and other stresses in air, water, and soil. The consensus of the scientific community is that environmental risk assessment is the most technically sound and cost-effective approach to providing the information needed to make decisions on the resolution of environmental problems. Environmental risk assessment provides a logical framework for comparing exposure with effects and provides an estimate of the probability that an effect will be observed. These attributes make the environmental risk assessment approach superior to other past and current approaches for assessing impacts on ecological resources.

Until ten years ago, impacts were assessed primarily in terms of effects only. Few mechanisms (except hazard assessment approaches) exist for linking exposure to effects and expressing the results in terms of probabilistic statements. Because an environmental risk assessment is able to articulate risk, the results of an environmental assessment are in a form that facilitates decision-making.

Critical environmental issues can best be addressed by the use of environmental risk assessment. If this approach is enhanced by the research identified in this document, it will be possible to establish priorities on the basis of comparative risks and then allocate limited resources to mitigate those problems that pose the greatest risk. The results of this effort will benefit our environment and our society.

Recognizing the value of applying the environmental risk assessment approach to environmental problem solving, the Society of Environmental Toxicology and Chemistry (SETAC) organized a workshop, "Consensus Research Needs and Priorities in Environmental Risk Assessment," to identify the research needed to enhance the development of environmental risk assessment methods. This report is a product of the workshop and can serve as the basis for an initiative to develop the resources needed to conduct the research identified.

This workshop is a continuation of a successful series of workshops called the Pellston Workshop Series. Since 1977, six workshops have been held, addressing a number of relevant environmental topics. These workshops have been organized and conducted by individuals who are SETAC members. Workshops held to date include:

- *Estimating the Hazard of Chemical Substances to Aquatic Life*—held in Pellston, Michigan, June 13-17, 1977, and published by The American Society for Testing and Materials as STP 657 in 1978.
- *Analyzing the Hazard Evaluation Process*—held in Waterville Valley, New Hampshire, August 14-18, 1978, and published by American Fisheries Society in 1979.
- *Biotransformation and Fate of Chemicals in the Aquatic Environment*—held in Pellston, Michigan, August 14-18, 1979, and published by American Society of Microbiology in 1980.
- *Modeling the Fate of Chemicals in the Aquatic Environment*--held in Pellston, Michigan, August 16-21, 1981, and published by Ann Arbor Science in 1982.
- *Environmental Hazard Assessment of Effluents*—held in Cody, Wyoming, August 23-27, 1982. Proceedings published by SETAC and Pergamon Press in 1985.
- *Role of Sediments in Regulating the Fate and Effects of Chemicals in the Aquatic Environment*—held in Florissant, Colorado, August 11-18, 1984. Proceedings to be published by SETAC and Pergamon Press in 1987.

1.2 SOCIETY OF ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY

The Society of Environmental Toxicology and Chemistry (SETAC) is a 1200-member professional society founded in 1979 to provide a forum for individuals and institutions engaged in the study of environmental problems, management and regulation of natural resources, education, research and development, and manufacturing and distribution. It is the only professional society that specifically brings together environmental scientists and engineers from academia, government, industry, and public-interest groups to provide research, education, and training in environmental risk assessment. SETAC provides a forum through meetings, publications, and workshops for communication among professionals involved in the use, protection, and management of our environment. The goals of SETAC are pursued through activities such as:

- Holding an annual scientific meeting comprising workshops and scientific paper presentations on topics related to environmental toxicology and chemistry.
- Publishing a monthly journal, *Environmental Toxicology and Chemistry*, a quarterly newsletter (SETAC News), and special publications (e.g., *Multispecies Toxicity Testing* and *Hazard Assessment of Effluents*).
- Organizing and sponsoring chapters nationwide to provide a forum for the presentation of scientific data and for interchange and study of information of more local concerns.
- Providing advice and counsel to technical and non-technical persons, groups, or institutions about scientific issues through a number of standing and ad hoc committees.

This workshop, "Consensus Research Needs and Priorities in Environmental Risk Assessment," was organized by SETAC's Technical and Governmental Affairs Committees to assess a critical need perceived by the membership to enhance capabilities through research for conducting environmental risk assessment. SETAC gratefully acknowledges the financial contributions of the workshop sponsors:

- U.S. Army Medical Research and Development Command
- U.S. Army Chemical Research Development and Engineering Center
- The Procter and Gamble Company
- The National Agricultural Chemicals Association
- Dow Chemical Company
- U.S. Environmental Protection Agency.

1.3 APPROACH TO DEVELOP CONSENSUS RESEARCH NEEDS AND PRIORITIES

To develop consensus research needs and priorities in environmental risk assessment, scientists representing a broad range of technical expertise were assembled for a one-week workshop. The workshop was held August 16-21, 1987 at the Village at Breckenridge, Colorado.

The workshop objectives were to identify specific research needs in environmental risk assessment, to enhance communication, and to provide a forum for transfer of information among researchers and decision-makers from government, industry, academia, and public-interest groups. Additional objectives were to identify research needed to solve current problems by means of proper environmental risk assessment, and to develop a strategy to enhance the use of environmental risk assessment in addressing environmental problems.

Workshop participants represented governmental organizations, universities, public-interest groups, industry, and contract research laboratories. Participants were chosen to provide the technical expertise needed to address research needs in environmental risk assessment. Technical expertise included aquatic and terrestrial toxicology, chemistry, environmental fate, transport, and modeling, and ecology.

During the initial phase of the workshop, keynote presentations were made by individuals representing SETAC, the U.S. Environmental Protection Agency's Office of Research and Development and Science Advisory

Board, the President's Office of Science and Technology Policy, trade associations, and universities. These speakers articulated key environmental risk assessment research directions from their organizations' perspectives, and illustrated approaches for best utilizing the results of the workshop to assist in the enhancement of the use of environmental risk assessment.

Prior to the workshop, each participant was asked to prepare a list of research needs to better improve our understanding and conduct of environmental risk assessments. Those preliminary research needs were then used as the basis for developing the consensus research needs and priorities. Participants were placed into one of six workgroups: Terrestrial Toxicology, Aquatic Toxicology, Chemistry/Fate/Modeling, Risk Assessment Methodology, Implementation, and Synthesis (Table 1.1). Each workgroup was responsible for the development and integration of research needs and priorities within its technical area in order to identify the technical research needed to best improve our understanding and use of environmental risk assessment. The Implementation workgroup had the task of preparing a plan on how to best enhance the use of environmental risk assessment in solving environmental problems, while the Synthesis workgroup was responsible for synthesizing the findings of the other workgroups into a united whole.

The outcome of the workshop is presented in this report. Section 2 provides a perspective on environmental risk assessment and discusses the benefits to society of applying environmental risk assessment to environmental problems. The adequacy of environmental risk assessment methods and research needs to improve those methods is described in Section 3. The application of environmental risk assessments to environmental problems is illustrated in Section 4. Research needs in environmental risk assessment, exposure analysis, and effects are identified in Section 5. Appendices A through D provide detailed explanations of those research needs presented in Section 5, including summaries of the issues involved, justifications for further research, and plans for that proposed research. Appendix E is a glossary of technical terms used in this report, and Appendix F is a roster of participants in the workshop.

TABLE 1.1 ENVIRONMENTAL RISK ASSESSMENT RESEARCH NEEDS WORKGROUPS

TERRESTRIAL TOXICOLOGY

Dr. Ronald Kendall* —Director, Institute of Wildlife Toxicology, Western Washington State University
Dr. Barbara Walton—Environmental Toxicologist, Oak Ridge National Laboratory
Dr. Bill Williams—Team Leader, Wildlife Toxicology, U.S. Environmental Protection Agency
Dr. Richard DiGiulio—Assistant Professor of Ecotoxicology, Duke University
Dr. James Gagne—Senior Product Development Manager, American Cyanamid Company
Dr. Molly R. Whitworth—Section Leader, Contaminant Ecology Research, U.S. Fish and Wildlife Service
Dr. Peter Greig-Smith—Head of Environmental Research Group, Ministry of Agriculture, Fisheries, and Food, United Kingdom
Dr. James Gillett—Director, Institute for Comparative and Environmental Toxicology, Cornell University

AQUATIC TOXICOLOGY

Dr. Wayne Landis* —Research Biologist, U.S. Army Chemical Research Development and Engineering Center
Dr. Thomas Sabourin—Environmental Toxicologist, Battelle, Columbus Division
Dr. Paul Mehrle—Chief Biologist, National Fisheries Contaminant Research Center, U.S. Fish and Wildlife Service
Mr. Steven Schimmel—Research Aquatic Biologist, U.S. Environmental Protection Agency
Dr. William Van der Schalie—U.S. Army Medical Research and Development Command

Continued

TABLE 1-1 ENVIRONMENTAL RISK ASSESSMENT RESEARCH NEEDS WORKGROUPS (CONTINUED)

CHEMISTRY/FATE/MODELING

Dr. Robert Huggett*—Head of the Division of Chemistry and Toxicology, Virginia Institute of Marine Science
Mr. Robert B. Ambrose—Environmental Engineer, U.S. Environmental Protection Agency
Dr. John P. Connolly—Associate Professor, Manhattan College
Dr. Ralph Portier—Assistant Professor, Louisiana State University
Dr. Robert Rapaport—Environmental Engineer, The Procter and Gamble Company
Dr. Armon Yanders—Director, Environmental Trace Substances Research Center, University of Missouri
Dr. William Wood—Team Leader, U.S. Environmental Protection Agency, Pesticide and Toxics

RISK ASSESSMENT METHODOLOGY

Dr. Richard Kimerle* —Senior Research Fellow, Monsanto Company
Dr. Robert Graney—Manager, Environmental Toxicology, Hoechst-Roussel
Dr. Glenn Suter—Research Staff Member, Oak Ridge National Laboratory
Dr. Peter Van Voris—Program Manager, Battelle Pacific Northwest Laboratories
Dr. Christopher Lee—Section Manager, Ecotoxicology Section, Unilever Research
Mr. Rodney Parrish—Research Aquatic Biologist, U.S. Environmental Protection Agency
Dr. Margaret Rostker—Special Assistant, Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency

IMPLEMENTATION

Dr. William Bishop*—SETAC Vice President, Associate Director, Environmental Safety Department, Procter and Gamble
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2.0 A PERSPECTIVE ON ENVIRONMENTAL RISK ASSESSMENT

Before 1977, potentially adverse environmental impacts were typically evaluated by considering effects only. Arbitrary toxicity limits were used to estimate the safety of chemicals. During the past ten years, the concept of coupling exposure with effects, a process called "hazard assessment," has been used to conduct environmental assessments.

The hazard assessment process calculates a quotient or margin of safety by comparing the toxicological endpoint of interest (usually an estimate of the safe concentration) to an estimate of the exposure concentration. A judgment is then made on the adequacy of the margin of safety. Toxicological and exposure data are collected in tiers, allowing for decisions to be made with minimum data, provided that the margin of safety is large enough. Large uncertainty factors have to be included in the margins of safety for minimum data bases, while smaller uncertainty factors can be used with larger data bases. The uncertainty factors that are applied to safety decisions come from a general understanding contained in published literature on the variability that exists in species responses, life stages, short- and long-term endpoints, and test methods.

The hazard assessment approach has been used over the past decade by industry and regulatory agencies in evaluating the safety of new and existing chemicals under the Toxic Substances Control Act (TSCA), pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), effluents under the Clean Water Act (CWA), and the cleanup of hazardous waste sites under the Comprehensive Environmental Response Compensation and Liability Act/Superfund Amendments and Reauthorization Act (CERCLA/SARA).

Risk assessment is the process of assigning magnitudes and probabilities to adverse effects resulting from human activities or natural catastrophes. In the last few years, risk assessment has been recognized as a valuable tool to support decisions about actions that may have undesirable effects. Risk assessment consists of formal scientific techniques that (1) integrate knowledge about a contemplated action and its possible effects, (2) account for uncertainty associated with that knowledge, and (3) express results probabilistically in order to account for both knowledge and uncertainty. Risk assessment provides a sound technical basis for making rational management decisions. Risk management is the process of making decisions about the acceptability of risks and the need for risk reduction.

Risk assessment was originally developed as a part of the actuarial techniques of the insurance industry to estimate probabilities of events that result in claims. It has been extended by engineers to estimate the probabilities of catastrophic failures of engineered systems such as aircraft and nuclear power plants. More recently, it has become an important tool in the health industry for estimating probabilities of diseases among people exposed to a range of toxic chemicals and mixtures such as cigarette smoke or emissions from coke ovens.

Environmental risk assessments estimate risks that may result from events in the environment. Most often they deal with pollution of the air, water, and soil. They may also be concerned with physical modifications of the environment and with natural catastrophes. The branch of environmental risk assessment that deals specifically with effects on plants, animals, and ecosystem properties is termed ecological risk assessment.

Environmental risk assessment differs from previous approaches to estimating environmental effects, such as hazard assessment, in that risk assessment employs scientific methods to estimate probabilities of clearly prescribed effects. Hazard assessments have relied more on margin of safety and the expert judgment of the assessor than on formal techniques such as mathematical and statistical models that define the magnitude of uncertainty in the effects and exposure estimates. While uncertainty has been recognized to exist, it has not been acknowledged that uncertainty results in some probability that effects and/or exposure will be more or less severe than expected. Advances made in assessment modeling, environmental chemistry, and environmental toxicology have begun to make it possible to use formal risk assessment methodologies.

An example of an environmental risk assessment is the National Crop Loss Assessment Network (NCLAN), which addressed the effects of ozone and sulfur dioxide on crop production. NCLAN had a clear endpoint — the reduced production of four major crops expressed in dollars. NCLAN developed a closely integrated program of experimentation and modeling and expressed the uncertainty of its results as probability-density functions on production losses for each alternate air quality criterion. Thus NCLAN provided the EPA with a clear expression of the consequences of alternative decisions. NCLAN and the few other examples of good environmental risk assessment have addressed major national problems at considerable expense. New methods must now be developed to make the benefits of risk assessment available to routine assessments such as registration of pesticides and toxic substances, prioritization of hazardous waste sites, natural resource damage assessments, and dredge-and-fill permits. To do so requires focused research applicable to environmental risk assessment methods.

Environmental risk assessment can provide the following benefits to the risk manager, the business and scientific communities, and the public:

1. *Environmental risk assessment will provide a firm scientific basis for decisions. This will improve public welfare and stewardship of the environment.*
2. *Improved understanding of risk and risk perception will result in improved communication of risk to the public.*
3. *Risk-based environmental decisions will provide a means of comparing risks so that resources can be efficiently allocated among environmental issues and rational policies can be formulated.*
4. *Environmental risk assessment will provide a means of incorporating uncertainty in the assessment process. The use of uncertainty measurements improves confidence in the decision-making process by evaluating the potential consequences of a decision based on incomplete knowledge. This is done by comparing the relative magnitudes of uncertainties about each step in the causal chain between the initial event (e.g., release of a toxic chemical) and ultimate consequences (e.g., destruction of a bird population).*
5. *Formal risk assessment will provide consistent results. It uses scientifically reviewed methodologies that are available to regulated entities and the public, thus increasing confidence in the decision process.*
6. *Allocation of resources for investigation and research on a particular environmental issue will be made effectively. This is done by addressing the sources of greatest uncertainty identified in the risk assessment process.*
7. *The ability to conduct consistent and comprehensive risk assessments will reduce the uncertainty associated with bringing new chemicals and technologies to market. It will increase the confidence of all sectors of the community in the safety of the environment, thus increasing support for innovation. This will increase the competitiveness of the business community by allowing it to take the lead in the introduction of new materials and processes.*

3.0 RESEARCH NEEDS IN ENVIRONMENTAL RISK ASSESSMENT

As a result of activities that have improved modern society's standard of living and the concurrent reliance upon the use of chemicals, we are faced with the dilemma of assessing potential risks to man and the environment. At the present time, we are limited in our ability to conduct scientifically defensible risk assessments for these chemicals. These limitations can best be addressed by a national research initiative.

3.1 LEGISLATIVE MANDATES

The goal of protecting and conserving our nation's living resources (forests, wetlands, fisheries, etc.) has a long history. Achievement of this goal has been codified in several pieces of legislation over the past two decades. Examples of such legislation include:

- National Environmental Policy Act
- Clean Water Act
- Federal Insecticide, Fungicide and Rodenticide Act
- Toxic Substances Control Act
- Comprehensive Environmental Response, Compensation and Liability Act
- Wetlands Protection Act
- Endangered Species Act
- Fish and Wildlife Coordination Act
- Federal Land Policy Management Act
- Migratory Bird Treaty Act
- National Fisheries Protection Act.

These laws address issues related to the assessment of impacts from existing and new technologies, protection of species diversity, conservation of natural resources, and assessment of the risks posed by the production, use, and disposal of pesticides and industrial chemicals. Implementation of this legislation at the federal, state, and local level can benefit from the application of a consistent, systematic framework for conducting environmental risk assessment. However, our present capacity to estimate ecological and environmental risks is not sufficient to ensure the prevention of other costly, and possibly irreversible damage to essential biogeochemical cycles or potential extinction of endangered species and ecosystems. *For these reasons, data gaps and methodological shortcomings in environmental risk assessment need to be addressed by a national research initiative.*

3.2 CURRENT LIMITATIONS IN ENVIRONMENTAL RISK ASSESSMENT

Current test methodology and specific endpoints have been designed to support the relatively simplistic, but nonetheless valid process of hazard assessment. Although many of the methods are scientifically sound and have been successfully used to support the needs of existing legislation, they have a number of limitations, sometimes severe, in relation to their utility in risk assessment. There are also gaps in available methodologies that must be filled in order to accomplish effective and comprehensive risk assessments.

At present, potential environmental impacts of chemicals are analyzed primarily through hazard assessments, which do not explicitly define ecological endpoints such as forest production or protection of endangered species, but only compare exposure and specific effect test endpoints. By only comparing exposure and test endpoints, hazard assessments ignore the complex dynamics of (1) contaminant concentration in each of the media to which the organism is exposed, (2) the duration of exposure, (3) the severity of effects, (4) the proportion of organisms that are affected, and (5) ecosystem-level considerations such as resistance and resilience.

Current exposure and effects methodologies do not provide the depth of understanding of the chemical and biological mechanisms that environmental risk assessment requires. Analytical chemical methods are inadequate to

provide a picture of chemical composition and speciation through time and are limited in their ability to identify the transfer coefficients essential to the modeling processes necessary for risk assessment.

In relation to the effects of chemicals, commonly used methods do not adequately address the effects of intermittent exposure, incremental dose, indirect effects, and the toxicity of intermediates and complex mixtures. Validated methods for determining effects at the population, community, and ecosystem level are also limited. The ability of current approaches to extrapolate results of laboratory tests into field situations is unknown and may lead to overconservatism in many cases. Our understanding of ecosystem structure and function is inadequate to determine when significant disruption is imminent and what constitutes unacceptable change. Similarly, while it is recognized that various compartments of the terrestrial and aquatic ecosystems may be resilient to xenobiotic impacts, these mechanisms are not understood. Few means exist to express dynamic ecosystem processes such as production, respiration, nutrient cycling, and energy flows in a form suitable for risk assessment.

Improved risk assessment methods will increase the efficiency and cost-effectiveness of environmental risk assessments, thus increasing the assessor's confidence in his or her conclusions and allowing better decisions to be made.

3.3 IDENTIFIED RESEARCH NEEDS IN RISK ASSESSMENT

Specific research needs that will address many of the limitations already discussed have been identified in this report. Correction of these deficiencies can only be accomplished through research projects designed to answer specific questions. Such research programs must address all components of risk assessment (Figure 3.1), and must contain a coordinated framework that emphasizes communication among the disciplines. More effective communication will ensure that toxicity test results, analytical chemistry measurements, and other measures are generated in a manner compatible with the risk assessment process.

As a starting point, funding in the area of risk assessment procedures should begin with a thorough examination of existing procedures and a review of the supporting literature. Reviewing past and current methodologies will provide insights into and understanding of the approaches that have been used and that appear to be most useful in assessing environmental risks. Directions for future efforts can be identified and refined by review of the past and present.

For the risk assessment process to work, specific effects endpoints need to be identified. Development of ecologically significant endpoints requires an increase in research on the biology, physiology, and ecology of terrestrial and aquatic biota. Greater understanding in these areas will enhance the ability of the risk assessor to interpret the ecological significance of observed changes and predict higher-level effects (e.g., population) from simple toxicological data bases. Environmental exposures need to be better quantified and the associated uncertainties identified. This can be accomplished by:

1. developing toxicity test procedures that more accurately reflect environmental exposure;
2. investigating the influence of behavior on chemical exposure;
3. better defining what to monitor and how to monitor in the environment;
4. developing approaches to determine whether a change is environmentally significant;
5. identifying techniques to extrapolate among geographical regions by using data from similar ecosystems; and
6. developing models that provide estimates of exposure. Such models are only useful if they can be parameterized with data available to the risk assessor and if they accept and integrate uncertainty estimates. Therefore, any environmental exposure research in the aquatic or terrestrial environments must consider these factors.

Models useful for predicting ecological effects are also needed. Currently, there are no generally accepted or commonly used ecological effects models. Development of these models also requires basic research on the biol-

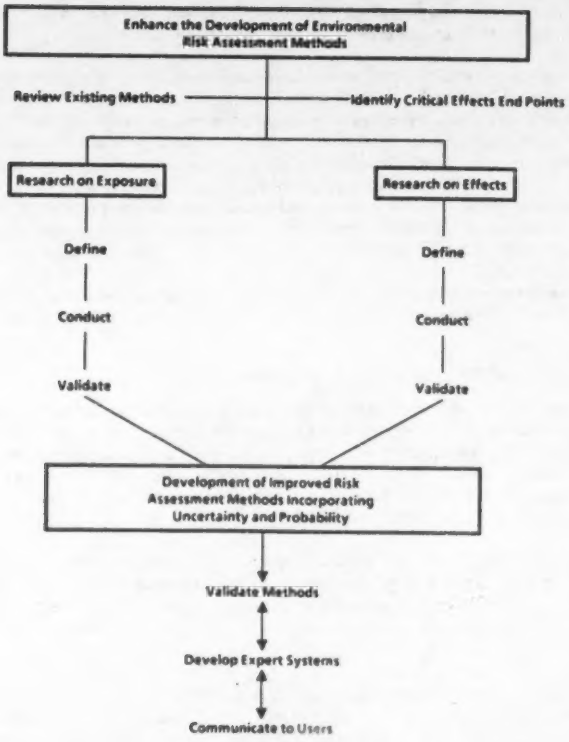

FIGURE 3.1 DEVELOPMENT OF ENVIRONMENTAL RISK ASSESSMENT METHODS

ogy and ecology of aquatic and terrestrial biota. For effects models to be useful, clearly defined endpoints must be established so that the models can be constructed appropriately.

The hazard assessment process now employed in most situations does not adequately include the uncertainty of the data estimates or of the model results. The environmental fate and effects research proposed during this workshop must include consideration of the variability and uncertainty inherent in measurements. Test procedures and models that include the concept of uncertainty need to be developed and refined, so that uncertainty can be incorporated into risk assessments and subsequently conveyed in a useful way to those who make or review decisions.

The need exists to make the best scientific expertise available for the risk assessment decision-making process. The use of expert systems in the risk assessment process can assist in achieving this goal. Once in place, expert systems will be used as a source of information in decisions dealing with the safety of chemicals in the environment.

Communication of the risks associated with the use and disposal of chemicals needs to be improved. The challenge is to reduce a very complex process to a simple, understandable, yet informative message that explains to regulators, those regulated, involved professionals, elected officials, and the general public how they are affected by the process. Research concerning the best and most appropriate mechanism to provide this information is needed.

The all-encompassing research need facing environmental risk assessment is validation of the process itself. Many of the needs discussed above can be investigated in large-scale validation studies. Critical needs such as endpoints, laboratory-to-field extrapolations, and understanding of the ecological significance of changes should be addressed. The output of such studies would provide risk assessors with the relationship between the amount of chemical and toxicological data collected and the resulting uncertainty in the risk assessment decision. Validation efforts should be undertaken in different types of environments and for chemicals of varying physical, chemical, and toxicological characteristics.

Section 5 and Appendices A, B, C, and D of this report contain specific research needs to advance the state of the art of environmental risk assessment. The proposed research initiative should address these needs.

4.0 APPLICATION OF ENVIRONMENTAL RISK ASSESSMENT TO ENVIRONMENTAL PROBLEMS

A multitude of existing and emerging environmental issues confront the nation and the world. Each specific issue can have impacts at local, regional, and even global levels, and can involve air, water, sediment, soil, and groundwater with multimedia interactions. Although the technology exists to solve each of these issues, the costs associated with many of the solutions are so large that cost-effective means of resource allocation must be found if timely and substantive efforts are going to be effected for all issues.

At present, all decision-makers associated with policy or risk management roles are limited in their ability to answer the following sequence of questions:

1. *Is there currently an ecological problem?*
2. *If so, what is the extent and magnitude of the problem?*
3. *What are the current trends and/or the anticipated future trends that define the potential problem?*
4. *What are the most probable causes of the problem?*
5. *What changes in policy or control mechanisms can be expected to reduce the current or potential risk?*
6. *What is the most cost-effective remedial action?*
7. *How do we measure the effectiveness of any remedial action?*

Environmental risk assessment can help answer the above questions and contribute to the development of cost-effective assessment and remedial strategies in several ways. First, by evaluating the existing scientific data bases, environmental risk assessment can quantify the magnitude and seriousness of identified environmental problems. Conversely, it can show that a low probability of effects exists. Where consequence predictions are surrounded by uncertainty, environmental risk assessments will recognize and quantify that uncertainty, thereby providing an essential element for decision-makers. Recently, for instance, qualitative and quantitative evaluations of the human and environmental risks from stratospheric ozone depletion have led to a re-examination of the research and regulatory priorities of this problem.

Second, the process of assessing today's risks reveals data gaps or uncertainties that signify the need for additional research. For example, accidental spills may have environmental impacts significantly different from those produced by chronic pollutant discharges. The need to understand how spills affect the long-term resiliency and recovery capabilities of ecosystems thus emerges as a research priority.

Third, the application of environmental risk assessment provides a quantitative measure of the reduction of environmental risk resulting from various remedial strategies. Thus, it provides a cost-effective basis for allocating resources.

The application of environmental risk assessment methods for evaluating and solving environmental problems is becoming widely used and is recognized as a scientifically sound approach, but this approach is currently limited by a lack of critical information in key areas. Additional research is needed to enhance the state of the art of environmental risk assessment procedures.

To demonstrate the need for additional research, examples are presented below to show how the environmental risk assessment approach could be applied to several of the following key national issues:

- Methods of proper waste disposal
  - —industrial waste
  - —municipal waste
  - —waste site remediation

- Protection of natural waters
  —surface water (streams, wetlands)
  —groundwater
  —coastal waters
- Impacts of genetically-altered organisms in the environment
- Safe and effective use of agricultural chemicals
- Control methodologies for non-point source contaminants
- Atmospheric process changes affecting biota
  —acid precipitation
  —ozone depletion
  —global warming—chemical contaminants
- Influence of sediments on water quality and biota
- Effects of complex chemical mixtures on biological systems
  —effluents
  —irrigation drainage waters
  —dredged materials
- Potential environmental effects of newly developed industrial chemicals
- Maintenance of natural resources and habitat quality
- Communication of risk information to various audiences, including scientists, regulators, policymakers, and the general public.

The following examples specify how environmental research assessment methods could be brought to bear on environmental problems related to waste disposal, biotechnology, agricultural chemicals, atmospheric contamination, complex mixtures, natural resource contamination, and groundwater quality.

4.1 WASTE DISPOSAL: ENVIRONMENTAL RISK ASSESSMENT

There is a clear need to extend the implementation of environmental risk assessment techniques into the overall strategies for disposal of industrial and municipal wastes and to improve the risk assessment methodologies being used. Application of environmental risk assessment procedures to waste disposal is a scientifically sound and cost-effective basis for making decisions on disposal and site cleanup methodologies as well as for providing a measure of the potential for environmental impact from past, present, or future disposal methods.

Wastes are currently disposed of in all environmental media by such routes as incineration, release of effluents, and deposition in landfills and septic systems. Tracking potentially toxic chemicals is a complex task, and the assessment of the risk associated with waste disposal will certainly benefit from improved understanding of the physical, chemical, and biological processes involved. Chemical transport from wastes through processes such as air emissions, land runoff, soil leaching, and sedimentation leads to the presence of potentially toxic chemicals in terrestrial and aquatic environments (Figure 4.1).

Research is proposed on exposure and effects to enhance the scientific community's ability to better use environmental risk assessment procedures in both forecasting and handling current problems associated with the fate, transport, and effects of toxic chemicals at waste sites. The benefit of such research will be the ability to make cost-effective scientific decisions about waste disposal alternatives. On the basis of quantitative risk measurement, prioritization of waste sites for remediation can be accomplished effectively. The potential exists to significantly reduce the nation's risk associated with disposal methods and waste site chemical contaminants.

The major inputs to environmental risk assessment models for waste disposal are the sources, exposures, and effects shown in Figure 4.2. Improved understanding and modeling of the relationships between the components

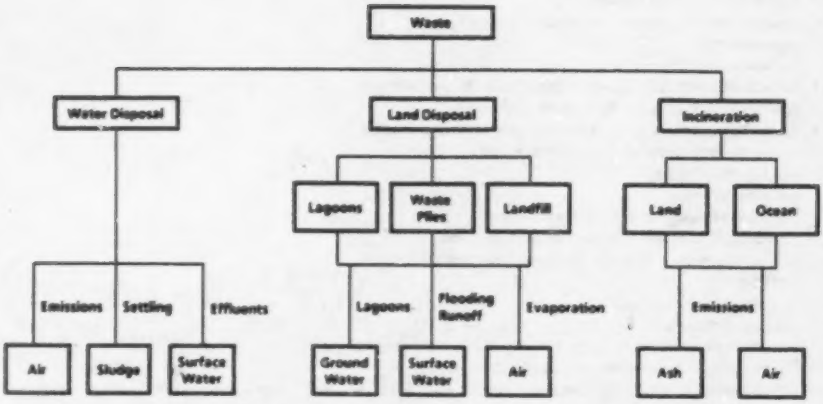

FIGURE 4.1 SUMMARY OF ENVIRONMENTAL FATE AND TRANSPORT PROCESSES OF DISPOSED WASTE

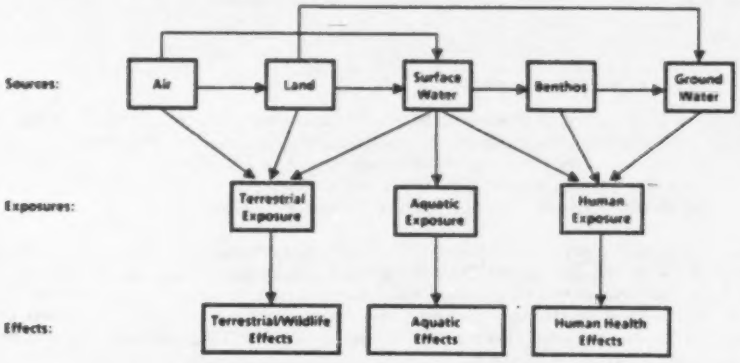

FIGURE 4.2 RELATIONSHIPS AMONG SOURCE, EXPOSURE, AND EFFECTS OF TOXIC CHEMICALS DERIVED FROM DISPOSED WASTE

shown in Figure 4.2 will be necessary to perform the appropriate risk assessments. To illustrate this need, two brief examples follow.

Example 1:

The movement of chemicals from one medium to another by sorption-desorption is a key factor in the issue of waste disposal and cleanup. Simply knowing that a toxic chemical is present in a given environmental compartment

is not enough. In order to know whether or not it will have an undesirable effect, we need to know how much of the chemical is available to living organisms in a form that can produce an effect. Modern analytical techniques can tell us that a chemical is present, even when it is present in ultratrace amounts, but these techniques do not usually tell us the extent of the biological availability or how the materials behave in association with various soils, sediments, or solvents. *Knowledge of the sorption-desorption behavior is critical for predicting rates of movement in aquatic, terrestrial and atmospheric media, and for assessing what this movement is likely to mean to the ecosystem.*

Example 2:

Contamination of groundwater aquifers that serve as drinking water sources can result from toxicants leaching from waste sites. Present methods are limited in their ability to quantify the risks posed by these activities because of the heterogeneous nature of the underlying strata and the channeling effects that can occur as a result of fractured media. At the present time, the effects of channeling result in non-quantitative measures of chemical movement through fractured strata. Present uncertainties in chemical transport contribute to unreliable estimates of exposure to target organisms via movement in the groundwater. *The proposed research is designed to improve estimates of chemical movement in fractured media and thereby enhance the overall risk assessment process.*

4.2 BIOTECHNOLOGY: ENVIRONMENTAL RISK ASSESSMENT

Biotechnology is an emerging science that deals with the intentional change of the genetic configuration of an organism (i.e., plant, animal, or microorganism). The objectives of these genetic changes are either (1) to produce a chemical, pesticide, or drug for use in commerce, or (2) to produce an organism that will have a beneficial effect when released to the environment. An example of the first objective is the production of human insulin by introduction of the appropriate gene sequences into a bacterium. In the latter objective, the organism might be a bacterium that is purposely sprayed on an agricultural field to act either directly as a microbial pest control agent or indirectly to produce a chemical that has a pesticidal effect.

Genetically-altered organisms are not limited to bacteria. An enormous research effort is currently underway to introduce herbicide-resistant plants that have been produced by splicing bacterial genes into their genome. In either objective, considerable concern has arisen over the potential environmental risks of either deliberate or accidental release of genetically-altered organisms into the environment.

The process of biotechnology environmental risk assessment is one that provides a quantitative estimate of the risk to the environment associated with the production of genetically-altered organisms. The application of risk assessment procedures to the biotechnology area is an emerging science that requires extensive investigation and research effort to develop and apply appropriate methodologies.

Biotechnology is a growing industry of great promise on an international scale. The benefits of applying accurate environmental risk assessments to this industry include protection of the environment and enhancement of the competitiveness of the U.S.-based biotechnology industry. The benefits of biotechnology include increased efficiency of agricultural production through development of disease-resistant plants, waste cleanup by means of genetically-designed microbes, production of pharmaceuticals and diagnostics, and the general resultant economic prosperity. Such benefits will not be achieved if we do not learn how to manage the risks associated with biotechnology in a cost-effective manner.

The research that is proposed in the biotechnology area is designed to enhance environmental risk assessment procedures for biotechnology by providing answers to critical elements of the risk assessment process. Examples of the types of questions that need to be answered are shown below. (Additional research needs are described in Section 5.)

1. What are the ecological effects of the introduced organism on the species composition, community structure, and metabolism (i.e., biogeochemical cycles) of an ecosystem?
2. What is the probability of survival, and what are the rates of reproduction and migration of a genetically-altered organism?
3. What is the significance and frequency of gene transfer from the genetically-altered organisms to naturally occurring organisms?
4. What are the parameters controlling the expression of the introduced genetic element in the environment?
5. What are the effects of ecological factors on the genetic stability of the altered organism?
6. What are the effects of the genetic background of the natural populations on the continued existence of the introduced genetically-altered organism and the inserted gene sequence?
7. Are there management strategies that lower the risks associated with a genetically-altered organism (i.e., suicide gene, containment organism sterility)?
8. What possible environmental risks can be attributed to the effluents, both chemical and biological, of biotechnological processes?

Research efforts to answer these and related questions will mean a significant enhancement of our understanding of and confidence in the rapidly expanding discipline of biotechnology and our ability to perform environmental risk assessments related to this new area.

4.3 AGRICULTURAL CHEMICALS: ENVIRONMENTAL RISK ASSESSMENT

Agricultural or plant protection chemicals are currently an essential component of agricultural production systems throughout the world and will remain so in the future. In short, these chemicals are unique in that they are intentionally released into the environment because of their benefits, even though by their nature, plant protection chemicals are toxicants that may affect non-target organisms. The use of environmental risk assessment methods for determining the environmental risk associated with intentional release of agricultural chemicals is an ideal approach for protecting the environment and enhancing the decision-making process. The large amount of data required for registration of agricultural chemicals lends itself to the application of risk assessment methods. To further enhance the risk assessment process for application to agricultural chemicals, additional basic research is required to understand key environmental processes.

The proposed research will reduce uncertainties associated with evaluating the safety of agricultural chemicals. This will be accomplished through better ways of quantifying risks, more efficient use of existing data and computer models, and improved measures of chemical exposure and biological effects. The net effect will be better management of environmental exposure and a reduction in the risk of ecological effects.

Under the Federal Insecticide, Fungicide and Rodenticide Act, EPA is faced with the difficult task of determining the potential adverse effects of agricultural chemicals. The procedure now used by EPA for estimating the potential adverse effects of agricultural chemicals involves comparing the concentration of the chemical that causes a toxic effect in laboratory and field tests with the concentration that is expected to occur in the environment. This environmental hazard assessment approach is termed the quotient or ratio method. For low-to-moderately toxic compounds, the estimated concentration in the environment is often much lower than the concentration that causes toxic effects. As a result, the decision that adverse effects are unlikely to occur can be made with a high degree of confidence. However, as the estimated concentration of an agricultural chemical gets close to the concentration that causes effects in laboratory and field tests, the decision that adverse effects would not occur in the environment becomes more and more difficult to make. The consequence of this latter situation is that agencies such as EPA must make a decision that could:

1. incorrectly determine that an agricultural chemical is safe, thereby sanctioning the use of a harmful chemical; or

2. incorrectly determine that an agricultural chemical is unsafe, thereby prohibiting the use of a compound that provides economic benefit to both the farmer and the consumer.

It is in everyone's best interest to minimize decisions such as those described above and to maximize the number of times we can correctly determine that an agricultural chemical is safe or unsafe within defined probabilities. This can effectively be accomplished through use of environmental risk assessment methods.

4.4 ATMOSPHERIC CONTAMINATION: ENVIRONMENTAL RISK ASSESSMENT

Environmental risk assessment methods are readily applicable to solving atmospheric contamination problems. The principle of comparing exposure concentrations with effect concentrations, combined with quantitative risk measurements, is a scientifically sound approach for assessing the impact of atmospheric contaminants. To accomplish this in a more effective manner, additional information is needed to enhance the state of the art for environmental risk assessment methods.

The benefit of applying environmental risk assessment to the problem of atmospheric contamination is that risk assessment provides a means for cost-effective resource allocation. Environmental risk assessment provides a formal, quantitative, and robust methodology for determining key atmospheric contaminants and measuring the risk of each contaminant to the environment. This approach can efficiently identify the particular chemicals responsible for environmental impacts as well as identify environmental compartments (regions, populations) at greatest risk to damage. Furthermore, environmental risk assessment can provide a quantitative analysis—including determination of uncertainty—of the expected outcomes of given scenarios of pollutant control. These results could then become a critical component of cost-benefit analyses of various emission control strategies.

Important issues in the area of air quality include global warming associated with increased carbon dioxide concentrations derived from fossil fuel combustion, stratospheric ozone depletion associated with fluorohydrocarbon emissions, catastrophic releases of toxic chemicals, long-range transport and deposition of synthetic organic compounds such as pesticides and PCBs, and the impacts of air pollution on aquatic and terrestrial ecosystems, including acid precipitation.

Some problems of atmospheric contamination, such as fugitive emissions from landfills, waste incinerators, and factories, occur on the local scale, and risk assessment provides an efficient approach for their analysis and solution. However, many critical problems are manifest on large scales—regional, national, and global. This added complexity of scale further compels use of formal risk assessment techniques.

Deposition of atmospheric pollutants and resulting impacts on terrestrial systems, particularly forests, exemplify the need for adequate large-scale atmospheric environmental risk assessment. Forest decline, apparently caused by air pollution, is severe in central Europe and is rapidly advancing in parts of western Europe. The precise causes of this decline are unclear, but they appear to be largely associated with emissions of nitrogen and sulfur oxides from fossil fuel combustion and agricultural fertilizers and the concomitant photochemical production of other oxidants, such as ozone and hydrogen peroxide. Forest decline is currently far less severe in the United States, being limited to certain high elevation sites in the Appalachian Mountains. However, it is crucial that the issue be addressed now in the United States before forest decline becomes widespread. At the present time, risk assessment methods are restricted by a lack of information on methods of chemical analysis, dispersion modeling, appropriate indicators of ecological effects, and source identification. Additional research is needed.

The application of environmental risk assessment to the problem of forest decline demonstrates a precise and effective methodology for determining key problem components and providing solutions. This approach can efficiently identify the particular compounds underlying impacts, including the concentrations, durations of exposure,

and seasonal distribution of these compounds. In addition, the key forest communities and regions at greatest risk in the United States can be determined.

Environmental risk assessments can provide quantitative analyses that include determination of uncertainty and provide expected outcomes of given scenarios of pollutant control. These results could then become a critical component of cost-benefit analyses of various emission control strategies. This approach can provide a way to enhance the management of our nation's resources.

4.5 COMPLEX MIXTURES: ENVIRONMENTAL RISK ASSESSMENT

Environmental risk assessment methods are directly applicable to the problems of complex mixtures. Complex mixtures include effluents and sludges from municipal and industrial sources; dredged materials from rivers, lakes, and estuaries; and stack emissions from industries, power plants, and other sources. Enhancement of environmental risk assessment methods will assist environmental managers in estimating the probabilities and magnitudes of undesired effects that may result from the release of complex wastes into the environment. More effective decisions about technological controls for industrial processes and source modification can thus be made.

Research is needed to enhance the use of environmental risk assessment methods. For instance, analytical chemistry research will yield methods that can better determine the vast array of chemicals in a waste. The research on the interactions of chemicals with solid particles and fluid transport phenomenon will allow more accurate predictions of where the wastes will go once in the environment. Biological research will provide insight into how the various living organisms that may be exposed will react to the mixture. Finally, the enhanced modeling capabilities that will result from this research will present decision-makers with a probabilistic determination of the impact of a complex waste. Then, options can be considered and judgments made to best manage our environmental and fiscal resources.

The potential application of environmental risk assessment methods to solving problems of complex mixtures can be exemplified by an analysis of the alternatives for disposal of sewage sludges. There are various alternatives, such as landfilling, incineration, biological degradation, and ocean disposal, each with its own inherent risks to the environment. *Environmental risk assessment methods can define the probability and magnitude of those risks and provide input into the decision-making process for selection of the most cost-effective and lowest-risk method for disposal of sewage sludges.*

Additional research has been identified which will enhance the risk assessment process for complex mixtures. Some examples of specific research needs are:

1. examination of chronic effects of complex mixtures on aquatic and terrestrial species;
2. determination of the impact of complex mixtures on the transport of chemicals in various environmental compartments; and
3. development of improved methodologies for evaluating the risk of complex mixtures.

4.6 NATURAL RESOURCES CONTAMINATION PROBLEMS: ENVIRONMENTAL RISK ASSESSMENT

The environmental risk assessment process can be applied to many natural resource problems. The benefit of using environmental risk assessment procedures for managing wetlands impacted by multiple stresses is the ability to assess the relative risk for each adverse effect, resulting in a more cost-effective means of allocating resources in order to address the stress which has the greatest risk of causing an adverse impact. This process can also be used to identify which risk measurements contain the most uncertainty and require additional research.

One major problem facing resource managers is the continued loss of wetland habitat because of drainage, urban development, and coastal gas/oil exploration and production. An additional problem is degradation of wetland quality, such as a reduction of submerged aquatic vegetation production because of sediment loading and adverse influences caused by contaminated dredged materials contained in or near wetland areas.

The application of the risk assessment process to a natural resources contamination problem—determining the probability of a dredge disposal site having an adverse effect on given wetlands quality—is exemplified as follows:

Effects Identification

In this example, the first step in the environmental risk assessment process is to determine the toxicity of the constituents identified in the dredged material. If all constituents are known and each constituent has a sound data base of known toxic effects on a wide variety of wetland biota, or if the complex mixture has a sound data base of known effects, the hazard can be calculated by a comparison of exposure and effect concentrations. However, little is usually known about the comparative toxicity of all the constituents to the biota of the wetland, necessitating extrapolation from limited data to a wide variety of species of concern in the wetland. Research is needed to help define the uncertainty with species-to-species extrapolations and to determine toxic interactions of various constituents.

Exposure Evaluation

The next step determines what the exposure concentrations of the dredged material constituents are to wetland biota. Exposure evaluation addresses such issues as the chemical properties of the dredged material constituents under varying conditions of temperature, pH, redox potential, sunlight, and the ability of vegetation and microorganisms to metabolize hazardous compounds. Exposure evaluation also addresses the impact of animal behavior on exposure regime as well as temporal and spatial changes in exposure and pulsed exposures. Research is needed on the bioavailability of toxic constituents sorbed to sediments, absorption/desorption rates for various organics and metals, and rates of transport to enhance the risk assessment process for dredge spoil disposal. It has been clearly shown that bulk chemical analyses do not predict bioavailability. Just because a chemical is present does not mean that it is bioavailable.

Risk Characterization

The last step of the environmental risk assessment procedure is risk characterization. In this step the resource manager reviews the probabilities for risk identified in the previous steps and weighs the estimated risk for potential impact of the disposal practice for all elements of concern. *The risk assessment process affords a sound basis for making this decision by providing a means for identifying the most cost-effective and lowest-risk method of disposing of the dredged material.*

4.7 GROUNDWATER QUALITY: ENVIRONMENTAL RISK ASSESSMENT

Given the importance of groundwater to society, strategies are needed to protect this valuable resource from contamination. The use of environmental risk assessment methods provides a rigorous and sound way of judging the risks and benefits of various management strategies for groundwater.

Groundwater is an important natural resource in the United States, accounting for 95% of the freshwater reserves of this country. Approximately half of the U.S. population relies on groundwater as its sole source of drinking water. This includes most major U.S. cities and virtually all (>95%) of the rural population. Groundwater is also used extensively in agriculture for irrigation purposes, and as processing water for a variety of manufacturing activities.

Each day, thousands of situations arise in which decisions are required to assess the impact of chemical contaminants on groundwater quality. Leachate from municipal and hazardous landfills, leaking underground storage tanks associated with local business and manufacturing activities, effluents from septic tanks, and other on-site wastewater treatment systems represent a few of the situations where environmental risk assessment techniques could guide the decision-making process.

Simulation models could link the chemical concentrations or application rate at the land surface with leaching and runoff rates and, ultimately, to concentrations in groundwater wells and adjacent surface water. Given local data on meteorology, hydrology, hydrogeology, soils, and land use, these models could draw upon a large chemical and biological data base in order to calculate the probability distribution of chemical concentrations throughout the local groundwater and adjacent ponds and streams. Effects models could then evaluate the risks to biota and humans. If the risks are judged unacceptable, the models could be used to investigate the consequences of using different chemicals or control strategies.

Some components of this risk assessment methodology exist today. Other components, however, are undeveloped or need improvement. The simulation models and data bases required for risk assessment must be developed, validated, and packaged into an easily used decision-support system, then rigorously tested under a wide range of conditions. Next, practical utility for aiding various kinds of decisions must be demonstrated. Finally, the software and data bases must be maintained and supported in a credible center of expertise.

Many of these decisions in groundwater quality protection can be categorized and classified into general approaches which in turn could be applied regionally or nationally. Similarly, the data bases (local and national) can aid in many types of problems and their solutions. *Overall, the science and technology of such a data base system are within reach, but a coordinated and intensified thrust from research through development and technology transfer is required in order for such a system to be implemented.*

5.0 SPECIFIC RESEARCH NEEDS IN ENVIRONMENTAL RISK ASSESSMENT

The preceding sections of this report have dealt largely with generic research issues related to environmental risk assessment. Attempts have been made to define the environmental risk assessment process in general, and to indicate the inadequacy of current risk assessment methods for providing a comprehensive basis for environmental decision-making. Several generic examples have shown that improved risk assessment procedures could substantially reduce the uncertainty and improve the scientific basis for decision-making in regard to key environmental problems.

This section identifies specific research needs in several key areas related to environmental risk assessment. This research is critical to the development of comprehensive environmental risk assessments and the use of scientifically based information in the decision-making process.

Research needs in environmental risk assessment can be grouped into several key areas, including risk assessment methodology, aquatic toxicology, terrestrial toxicology, and chemistry, fate, and modeling. Risk assessment methodology primarily involves the assumptions and approaches used to make risk assessments, and therefore can be grouped along functional lines. Research needs in the other disciplines, however, cover a much broader range of areas. In this section, they will be grouped into exposure and effects components, the two key elements in the environmental risk assessment process.

5.1 RISK ASSESSMENT METHODOLOGY

Research needs for improving the methodology and approaches for environmental risk assessments can be divided into seven main categories:

1. Validation of risk assessment procedures.
2. Evaluation of existing risk assessment procedures.
3. Development of risk assessment expert systems.
4. Development of transport, exposure, and effects models for risk assessments.
5. Identification of critical assessment endpoints.
6. Estimation of uncertainty in risk assessments.
7. Communication of the risk assessment process.

Details on each of these research needs, including the environmental issues they address, justification for the proposed research, and a suggested research experimental plan are given in Appendix A.

5.2 AQUATIC TOXICOLOGY

Research needs for improving environmental risk assessment efforts in the area of aquatic toxicology are given below. These needs are grouped into two broad categories, exposure-related needs and effects-related needs, and are listed in order of priority within each category.

Exposure:

1. Bioavailability of chemicals from sediments.
2. Microbial ecology of aquatic ecosystems.
3. Fate and transport of genetically-altered organisms.

Effects:

1. Biochemical/pharmacological/toxicological mechanisms.
2. Prediction of ecosystem stress from controlled laboratory and field investigations.

3. Quantitative structure-activity relationships and physiological/pharmacokinetic models.
4. Identification and measurement of ecosystem stress.
5. Sublethal effects of chemicals in aquatic organisms.
6. Interspecies extrapolation.

Detailed discussions of these needs in aquatic toxicology can be found in Appendix B.

5.3 TERRESTRIAL TOXICOLOGY

Research needs for improving environmental risk assessment efforts in the area of terrestrial toxicology are given below. These needs are grouped into two broad categories, exposure-related needs and effects-related needs, and are listed in order of priority within each category.

Exposure:

1. Exposure evaluation for nonaccumulating and accumulating chemicals.
2. Biotransformation and biological availability of contaminants in the terrestrial environment.
3. Routes of exposure and uptake of chemicals by plants and animals.
4. Factors affecting the exposure of terrestrial organisms to chemical contaminants.
5. Identification of sentinel species.
6. Impact of microorganisms and vegetation on chemical concentrations in soils.
7. Influence of sensory detection on organism exposures.
8. Influence of chemical and biological transformations on exposure.

Effects:

1. Comparative biochemistry and physiology.
2. Sublethal responses.
3. Interspecies extrapolation.
4. Population-level effects.
5. Community-level responses.
6. Behavioral toxicology.
7. Effects of environmental factors on toxicity.
8. Predicting ecosystem effects from chemical concentrations.
9. Toxicity of complex mixtures.
10. Patterns of response related to the duration, frequency, and intensity of exposure.
11. Extrapolation of toxicity data bases to wildlife risk assessments.

Detailed discussions of each of these research needs are included in Appendix C.

5.4 CHEMISTRY, FATE, AND MODELING

Research needs for improving environmental risk assessment efforts in the areas of chemistry, fate, and modeling are given below. These needs are grouped into two broad categories, exposure-related needs and effects-related needs, with specific needs listed in order of priority within each category.

Exposure:

1. Analysis of complex mixtures.
2. Development of computerized chemical data bases.
3. Kinetics of sorption-desorption.
4. Deposition and resuspension of particulate matter.
5. Biodegradation kinetics.
6. Solute transport in fractured media.
7. Atmospheric transport and fate processes.

8. Fate and transport of genetically-altered organisms.
9. Chemical loading.
10. Bioavailability of chemical toxicants.
11. Three-dimensional transport in complex ecosystems.
12. Field validation of exposure models.
13. Probabilistic exposure models.
14. Multimedia transport models.
15. Linkage of exposure and effects models.
16. Development of expert systems for environmental risk assessment.

Effects:

1. Relationships between body burden and toxic effects.
2. Toxicity of metabolites.
3. Toxicity of complex mixtures.
4. Toxicant effects on ecosystems.

Detailed discussions of each of these research needs can be found in Appendix D.

Dr. ADAMS. Thank you, Mr. Chairman, for the opportunity to speak on behalf our society. I'll be very brief and to the point.

The purpose of the Society's workshop was to identify research needs in risk assessment. We have done so and have submitted a copy of our report to your Subcommittee.

In essence, what it's saying is that we have identified some areas where basic research is needed to better enable us to assess impacts of man's activities on the ecosystem, and we differentiate between human health risk assessment and environmental or ecological risk assessment. We are dealing with ecological risk assessment, and so in that sense we are supporting some of the earlier statements made today about the need for increased funding at the basic level.

It is our feeling that some of the very basic tools that we need and that the Agency needs, industry needs are lacking in our ability to assess risk. We have come a long way, but our science is still young. A few years ago, things like mercury and DDT occupied our minds and at that time we were unable to make predictive judgments. Today we have come a long ways from that, but we need to put an increased funding in areas like structure activity relationships, multiple toxicant interactions—and an excellent example of a program like that was conducted and has been ongoing at the Duluth Laboratory in Minnesota. That program is currently being limited in resources and we think that kind of research needs to continue and be expanded.

Our overall documents lists a number of areas that need research. In essence, to be brief, I would like to say that we support a very, very large initiative. We would like to see some new monies put into the Agency beyond that which is existing. We are aware of a $10 million reallocation of resources within the Agency, $3 million for '88 and $7 million for '89 for use in their Reducing Uncertainty in Risk Assessment Program. We think that additional funding is needed in this area, and the Society supports allocation of new monies into this area.

This concludes my remarks. I would be glad to answer specifics as to what we think some of the research projects should be.

Mr. SCHEUER. What some of the research projects should be?

Dr. ADAMS. Yes.

Mr. SCHEUER. Why don't you tell us that?

Dr. ADAMS. Okay. For example—

Mr. SCHEUER. This is what it is all about.

Dr. ADAMS. Okay. For example, the Agency is currently involved in developing criteria like the water quality criteria for sediments. We are aware of sediment contamination around our nation and the ability to develop these sediment criteria for the protection of aquatic sediments is severely hampered by our inability to understand the transport of chemicals to and from sediments. This applies not only to the aquatic environment, it applies to Superfund sites where soils are contaminated. The same principles apply and the ability to predict and understand what controls movement of chemicals from soils is severely limited at this time. We can do it for a few classes of compounds, but not very many.

The current state-of-the-art of risk assessment is limited by our inability to do good quantitative structure activity.

Mr. SCHEUER. Quantitative structure activity?

Dr. ADAMS. Yes. In other words, if we understand one or two—some of the physical/chemical properties of a given class of compounds, can we extrapolate the data to other chemicals in the same class? That kind of research has been ongoing in the Agency, but needs to be pushed further. It is the basis for making risk assessments without having to collect all of the data for each chemical. We can't measure everything all the time. We have to be able to extrapolate and these types of programs take basic research.

The Society as a whole is appalled by the lack of money that's put into the Exploratory Grants Program. We have many members of our Society that of course are in academia, and it has been extremely frustrating in the last few years to see the source of money dry up and the Agency over time has been one of the primary sources of money for basic research in ecological risk assessment, and to see that totally dry up is really appalling from our Society's point of view.

I think I will conclude my remarks with that.

Mr. SCHEUER. Thank you very much. Dr. Luthy?

Dr. LUTHY. Yes, Mr. Chairman. It is an honor to testify this afternoon on behalf of the Association of Environmental Engineering Professors. We wish to express the views of the Association on the inadequacy of EPA's Program for Investigation Initiated Grants and Training of Graduate Students in Environmental Engineering and Science.

In many ways my comments will complement those of Dr. Vaun Newill and Dr. Roger Cortesi, who have spoken about the inadequacy of the Exploratory Grants Program.

University research in environmental engineering and science helps the EPA mission in two ways. First, university research helps to formulate effective policies and control strategies, and secondly, university research results in the production of a highly trained individual who can help satisfy manpower requirements.

I want to speak briefly to each of these points, first, with respect to the benefits of the research itself. Research is important in environmental engineering and science because it is the only mechanism we have to identify unforeseen problems, to develop new knowledge on environmental protection needs and controls, and to apply advances in science and engineering to achieve our goals most efficiently.

These issues are particularly important today, because of (1) the increase in the many complex and interdependent problems to be addressed by the EPA; (2) the greater need to understand more of the transformation and fate of contaminants in the environment; (3) the greater need for rational and verified models to answer questions involving risk and uncertainty; and (4) the challenge presented by the national goals of achieving waste minimization using the most cost efficient strategies.

The way in which we achieve these objectives require that we have adequate numbers of well trained individuals, and this brings me to second point, and that is the role of research in satisfying manpower needs.

89-070 O - 88 - 3

Graduate level education is an absolute necessity for training an environmental engineer. Undergraduate education provides only a brief introduction to the field.

It is the individual with the master's degree or doctorate who possesses the skills to become a competent designer, evaluator, project leader or a decision maker. Despite the growing need for environmental engineers, we are producing fewer graduates. Our association's own data show a 38 percent decline in the number of graduate environmental engineers since the era of the EPA training grants in the mid- 1970s.

This decline appears to be the result of a lack of funds for graduate student support. Today the principal mechanism for graduate student support depends on research grants, the funding of which have not kept pace with the manpower needs. We also face a challenge in attracting high caliber graduate students, who are drawn to other disciplines in engineering which are particularly well funded, such as electrical and computer engineering.

Therefore, we face a problem, both with respect to quantity and quality of the environmental engineering graduates. The Association of Environmental Engineering Professors recommends that these various problems may be most efficiently addressed by invigorating an investigator initiated, peer reviewed research grants program. Investigator initiated grants serve the dual purpose of addressing the basic research need and training of future practitioners. The peer review process also serves to assure the highest quality results.

In summary, this type of research program is the best way to achieve the greatest creativity and innovation in research, to bring the best faculty talent to address the needs of the EPA, and to produce competent engineers and scientists with the greatest diversity of problem solving skills. Thank you.

[The prepared statement of Dr. Richard G. Luthy follows:]

Association Of Environmental Engineering Professors

15 April 1988

Honorable James Scheuer
Chairman, Subcommittee on Natural Resources,
Agricultural Research and Environment
Committee on Space, Science and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Chairman:

The Association of Environmental Engineering Professors represents faculty at approximately 100 universities engaged in teaching, training and research in environmental science and engineering. I wish to express the views of our organization concerning the adequacy of EPA's programs for providing university investigator grants and training of graduate students in areas of environmental science and engineering.

University environmental science and engineering research helps the EPA to accomplish its mission in two ways. First, the results of the university research help formulate national environmental policy and more effective control strategies. Secondly, university research results in the production of highly-trained graduates who can help satisfy manpower shortages in environmental science and engineering.

In most instances, a graduate level education is required in order to attain technical competence in environmental sciences and engineering. Usually, it is individuals with graduate-level education who become principal scientists and engineers, project leaders, and decision makers. These individuals play an essential role in implementing environmental policy and regulation. Unfortunately, in recent years we have been producing much smaller numbers of graduates in environmental science and engineering despite the greater need. This problem is attributable in many respects to decreased levels of research support for individual investigator grants in environmental sciences and engineering.

Our organization conducts an annual survey of graduate student enrollment in environmental engineering. The raw data show that since the era of the EPA training grant programs in the mid

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1970's there has been a 38% reduction in the number of full time equivalent graduate students enrolled in environmental engineering. Today, in the absence of a training grant program, the principal mechanism for support of graduate students in environmental engineering is through research funding. However, research funding has not kept pace with the demand for environmental engineers. This problem has been recognized also by practitioners. As noted this year by Dr. Paul Busch, president of the American Academy of Environmental Engineers, which represents many environmental engineers in practice, "more than ever, environmental engineers are in short supply."

Compounding this problem is the challenge presented to graduate enrollment in environmental engineering by the attractiveness of graduate education in other disciplines of engineering, particularly electrical and computer engineering, which have received strong research support through the Department of Defense. The very best graduate students will gravitate towards those programs which are well funded. Consequently, environmental engineering faces problems with respect to both the quantity and the quality of our graduates.

Research funding in environmental engineering is essential for resolving the many complex issues to be addressed by the EPA. Graduate research support in environmental engineering has not kept pace with EPA's growing regulatory activities in areas such as toxic chemicals, hazardous wastes, and effects of atmospheric pollutants.

The Association of Environmental Engineering Professors recommends that these various problems may be alleviated in part by invigorating an EPA individual investigator, peer-reviewed, research grants program. Individual investigator grants address a basic research need, as well as provide training for future practitioners. The peer review process serves to ensure high quality research. The individual investigator grant proposal is the best mechanism to help bring creativity and innovation into university research. The best faculty research talents across the United States will be serving the EPA and producing competent graduate engineers with the greatest diversity of problem-solving skills.

Thank you for your attention.

Sincerely,

Richard G. Luthy

Richard G. Luthy
President

Mr. SCHEUER. Thank you very much. Let me ask you all a few questions, and you can answer if you wish.

SETAC, which is the Society of Environmental Toxicology and Chemistry, recommends a $750 million, ten year program of interagency research to improve environmental risk assessment.

In your views, what do you envision to be the failures of proceeding along this line? What would be the price tag for failure to follow that recommendation?

Dr. ADAMS. I'll take a stab at that. We perceive the failure of putting together the kind of program that we are talking about as being one of continuing—to be unable to answer two environmental questions that deal with a wide array of problems, whether we are talking about acid rain, whether we are talking about global warming, whether we are talking about hazardous waste—whatever the major issue is, the lack of proper risk assessment means that we are going to continue to assess these questions in piecemeal, that we are always going to be in a position of retrospectively trying to answer the question of whether it is a problem or not instead of as a nation putting our best foot forward and being anticipatory of problems. That is the major failure that I see.

Mr. SCHEUER. Do either of you, Dr. Luthy or Dr. Bishop, want to make a comment?

Dr. LUTHY. I agree with those comments. Another way to state it is that it is important to learn what we don't know.

Mr. SCHEUER. Well, that's putting it very succinctly. Are these recommendations the consensus of industry representatives, as well as representatives from the various environment groups?

Dr. BISHOP. The Society of Environmental Toxicology and Chemistry by its charter requires that its board of directors as well as its general membership be equally composed of scientific professionals from governmental agencies, industry, academic institutions and public interest groups, so the 1300 members of SETAC are equally distributed among those various interests.

Dr. LUTHY. The Association of Environmental Engineering Professors has a sister organization, the American Academy of Environmental Engineers, which represents many environmental engineers in practice. Their President, Dr. Paul Bush, has noted that more than ever environmental engineers are in short supply, and he was written editorials in their publications this year on that matter.

Mr. SCHEUER. Very good. Taking the entire research agenda outlined by SETAC, putting in all the various challenges in some kind of priority order, which ones would be at the top near the top of the list?

Dr. ADAMS. We believe as a whole—I'm reflecting on what was stated at our workshop, and some of the priorities that consistently came out from all of the work groups that were there included things like how do we assess chemical interactions?

Mr. SCHEUER. Chemical interactions?

Dr. ADAMS. Chemical interactions. When will we as a society be able to assess chemicals in the environment beyond one chemical at a time?

Mr. SCHEUER. Beyond what?

Dr. ADAMS. One chemical at a time. How do we deal with—

Mr. SCHEUER. Elaborate on that question.

Dr. ADAMS. Yes?

Mr. SCHEUER. Are you talking about analyzing the interaction of several chemicals in the atmosphere?

Dr. ADAMS. Yes—or several chemicals in an aqueous media.

Mr. SCHEUER. Are important?

Dr. ADAMS. Yes, it is important, and we know it's important and we are beginning to deal with that, for instance, in the effluent permitting discharge system that is in place by requiring organism monitoring of those effluents leaving discharge points. But at best we are only beginning to understand chemical interactions and to date we have always looked at one chemical at a time in making our assessments. We are beginning to recognize things like deforestation incorporating a whole broad host of chemicals and environmental factors, and to look at it one piece at a time is not doing the proper job. That is one of the key items that came out at the top.

Another top priority was really to improve the risk assessment process itself. We are a young science in terms of environmental sciences. You compare us with some things like chemistry and physics and mathematics and we have only really begun to put in place the tools that are needed to do good risk assessment in the last few years. This needs to be improved.

Clearly, communication of risk to the public is important. We recognize that as scientists we deal with a language in terms—in a form that is not easily understood by the public, and we think part of that risk assessment program should be risk communication. I think, as a little bit of an aside, that the EPA put out a document last year called their "unfinished business" document that really challenges whether or not we are dealing with the right issues in society and so in picking up on that, I would say that the concept of risk itself must be applied to management decisions and in helping the agency and the various agencies, not just the EPA but the various agencies, deal with those things that present real risks to society.

Perhaps one of my other colleagues would care to make a comment.

Dr. BISHOP. I'll just expand a little bit on that as a participant in the workshop and say there is a fundamental difference that has to be recognized between health risk assessment and ecological risks.

Dealing with health, we are dealing with the well- being and integrity of the individual organism. If we are dealing with ecological assessment, we are trying to measure and evaluate what constitutes an unacceptable level of change to a population, a community or an ecosystem. They are very easy to intellectualize. They are very difficult to manipulate experimentally, and so we are faced with regulatory requirements which drive us in the direction of protecting ecosystems without having fundamental basic research to understand what are the key processes that regulate ecosystems and what constitutes an acceptable and unacceptable level of change.

Dr. LUTHY. I could speak just briefly to what risk means to me as an engineer, and one such related issue is how clean is clean? We don't have a good understanding of what our targets should be in

the case of remediation. Also we don't have a good understanding of the reliability of control technologies for hazardous wastes. Another area lacking adequate research is the subject of in situ cleanup of contaminated ground waters and sediments. There is awful lot of empiricism, a lot of trials being done, but not a lot of science.

Also, there needs to be more research on the management of resources. We can look to the billions of dollars that are being spent to clean up hazardous waste, and we could ask the question how wisely are these monies being spent. What is the role of computer aided engineering and the role of expert systems in such a domain?

These are all areas requiring research.

Mr. SCHEUER. Well, I appreciate your testimony very much. You have all been very helpful.

During the '60s and '70s, the Government used to fund training grants for graduate students in environmental sciences. Which agencies funded these programs and why were they terminated? Is there any money currently available?

Dr. LUTHY. I can speak to that from the point of view of a professor in Environmental Engineering. Originally there were training grants that were funded by the U.S. Public Health Service, and thereby the predecessor agency to the EPA. During the 1970s—or I should say the early '70s and middle '70s, there were training grant programs available from the EPA. That money was mainly used to train engineers to design systems for treating municipal wastewater and for treating water for domestic use. In other words, it was all under the guise of the Clean Water Act.

Those engineers served a very useful purpose, but their skills are not the skills that we need today in the area of hazardous waste management, waste minimization, and cleanup of contaminated systems. We have greater needs today in environmental engineering, there are more complex problems to address, and we have no training grants program.

What we do today is rely on is our own faculty research contracts to train graduate students. This is the principal source of support of master's and doctor's degrees. At U.S. universities it is funding from those research contracts that supports graduate students, and those funds are not adequate to do the job.

Mr. SCHEUER. Well, I'm going to go over to the Floor now. There is a series of roll call votes. We are going to send you some questions by mail. I appreciate your testimony very much. It has been very stimulating. You have been very thoughtful, very solid professionals, and I want to express my appreciation for your presentations. Thank you very much.

Dr. BISHOP. Thank you. Thank you, Mr. Chairman.

Mr. SCHEUER. The meeting is adjourned.

[Whereupon, at 3:52 p.m., the Subcommittee recessed, to reconvene at the call of the Chair.]

APPENDIX

QUESTIONS AND ANSWERS FOR THE RECORD

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
RESEARCH AND DEVELOPMENT

Honorable James H. Scheuer
Chairman, Subcommittee on Natural
Resources, Agriculture
Research and Environment
House of Representatives
388 House Annex 2
Washington, DC 20515

Dear Mr. Chairman:

At the April 21, 1988 hearing concerning the fiscal year 1989 budget for research and development programs at the Environmental Protection Agency, held by your Subcommittee, you requested that we provide answers to written questions for inclusion with the hearing record. Enclosed are answers to all questions for inclusion in the hearing record except for questions 2, 4, 5 and 6 which were granted an extension by Wesley Warren of your staff.

If I can be of further assistance to the Subcommittee, please feel free to contact me directly or Oscar Morales, of my staff, at 382-7468.

Sincerely,

Vaun A. Newill, M.D.
Assistant Administrator
for Research and Development

Enclosures

QUESTION #1

QUESTION: What level of resources did EPA request from the Administration for FY 89 EPA research and development programs?

ANSWER: EPA requested a total of $402.7 million for research and development activities in its submission to the Administration. This amount included $330.4 million for the Operating Programs, $70.9 million for Superfund, and $1.4 million for the LUST Trust Fund.

QUESTION #3

The funding history of the Office of Research and Development is as follows:

EPA Office of Research and Development
Historical Budget Authority - Salaries & Expenses Appropriation
Nominal vs. Constant 1982 Dollars

(Thousands of Dollars)

Nominal Dollars	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Personnel Costs & Benefits	$63,157.9	69,999.2	68,745.4	67,577.9	68,705.5	73,002.2	75,098.1	77,066.0	78,728.5	75,563.2
Other Expenses	41,826.9	32,409.0	33,090.0	30,575.2	25,654.6	32,250.0	25,185.8	28,909.5	28,008.6	34,873.6
Total Nominal Dollars	$104,984.8	102,408.2	101,835.4	98,153.1	94,360.1	105,252.2	100,283.9	105,975.5	106,737.1	110,436.8
Constant 1982 Dollars 1/										
Personnel Costs & Benefits	$72,205.2	73,351.4	68,745.4	64,978.8	64,138.8	65,767.7	67,087.8	67,324.2	67,272.1	63,301.7
Other Expenses	49,464.2	34,507.0	33,090.0	29,788.8	24,442.3	30,126.1	23,072.4	26,267.0	24,635.9	29,523.9
Total Constant Dollars	$121,669.4	107,858.4	101,835.4	94,767.6	88,581.1	95,893.8	90,160.2	93,591.2	91,908.0	92,825.6

1/ Computed using OMB inflation adjustment figures for Federal Civilian Pay and Federal Non-Pay categories.

(#3 Continued)

The funding history of the Office of Research and Development is as follows:

EPA Office of Research and Development
Historical Budget Authority - All ORD Appropriations
Nominal vs. Constant 1982 Dollars

(Thousands of Dollars)

Nominal Dollars	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Personnel Costs & Benefits	$63,157.9	70,184.9	70,270.3	68,825.7	70,705.7	75,532.9	78,473.0	80,898.5	83,746.1	81,276.1
Other Expenses	275,307.9	287,909.0	200,367.3	156,897.6	178,365.1	227,327.8	243,957.3	259,654.5	268,576.6	293,748.0
Total Nominal Dollars	$338,465.8	358,093.9	270,637.6	225,723.3	249,070.8	302,860.7	322,430.3	340,553.0	352,322.7	375,024.1
Constant 1982 Dollars 1/										
Personnel Costs & Benefits	$72,205.2	73,545.9	70,270.3	66,178.6	66,006.1	68,047.7	70,102.7	70,672.2	71,559.5	68,087.5
Other Expenses	325,577.0	306,547.1	200,367.3	152,862.0	169,936.3	212,356.7	223,486.0	235,920.9	236,235.9	248,686.1
Total Constant Dollars	$397,782.2	380,093.0	270,637.6	219,040.6	235,942.4	280,404.4	293,588.7	305,593.1	307,795.4	316,773.6

1/ Computed using OMB inflation adjustment figures for Federal Civilian Pay and Federal Non-Pay categories.

QUESTION #7

QUESTION: If the schedule for the next scientific assessment of ozone depletion under the Montreal Protocol is accelerated, what research results would EPA be able to produce in time for consideration in such assessment?

ANSWER: Assuming the minimum of eleven signatures, the protocol will enter into force January, 1, 1989. (Article 16). Beginning in 1990 and at least every four years thereafter the parties shall assess the control measures....on the basis of available scientific, environmental, technical and economic information. At least one year before each assessment, appropriate panels of experts shall be convened (Article 6).

If the 1990 scientific assessment is accelerated, EPA could present some preliminary results from on ongoing research on the terrestrial and aquatic effects of UV-B on food plants, forest trees, and selected aquatic ecology related to fisheries. However, results from our new research, now being planned and soon to be initiated, may or may not be available in time.

QUESTION: #8

QUESTION: In March, 1988, a new scientific assessment of the ozone depletion issue concluded that there was evidence of a global average decline. Does this new scientific consensus provide conclusive proof for policy purposes, or is there still a need for EPA to carry out its proposed research program on ozone depletion?

ANSWER: Measurement of the decline of stratospheric ozone levels provides an indication of the expected increase in UV-B radiation reaching the earth's surface; as ozone levels decline, UV-B increases. Although there may be a scientific consensus on ozone depletion, there is still very little data on the level or extent of damage from increased UV-B. Before we can provide policy makers information on how to remedy this damage, we must provide them with a measure of the extent of this damage.

EPA's research program is focused on what effect the increased UV-B will have on food plants, man's food supply, and the health of those exposed to large doses of UV-B. Without this kind of research, policy makers would be at an extreme disadvantage. There is still a need, therefore, for research on the effects of the damage, especially in view of the long-term duration of CFC's, the major causative agent of ozone destruction.

QUESTION #9

QUESTION; How is the Interagency Committee for Stratospheric Ozone Protection, established under the Clean Air Act, currently functioning? Which EPA office is responsible for taking the lead with this committee?

ANSWER: The Interagency Committee for Stratospheric Ozone Protection (ICSOP) was established under the authority of Section 153 (f) (1) of the Clean Air Act, which directs the EPA Administrator to coordinate Federal stratospheric ozone depletion research. Currently there are nine member agencies including EPA on the committee. The group convenes on an as needed basis rather than on a fixed time schedule.

The charter establishing the ICSOP designates the Assistant Administrator for ORD as the chairman. ICSOP has not met formally in the last year, but individual members have.

QUESTION #10

QUESTION: How is EPA implementing the Congressional directive to establish a $10 million program for reducing uncertainty in risk assessment?

ANSWER: In FY 1988, $3 million has been identified for research to reduce uncertainty in risk assessment. These resources will be used to address uncertainties in health risk assessment. A research plan which describes the program and research program to be undertaken will be submitted to Congress in early July after completion of reviews by an ad hoc panel of external scientists for scientific merit and appropriateness and by OMB. The ad hoc panel review was generally favorable with several suggestions for improving the plan that are now being integrated into the plan. The four major areas to be addressed are: 1) Analysis of Uncertainty in Risk Assessment; 2) Integrated Exposure Assessment; 3) Physiologically Based Pharmacokinetic Models; and 4) Biologically Based Dose-Response Models. Research on this program is beginning and will continue through FY 1989.

In FY 1989, this research program will continue and be increased to $10 million. The distribution of funds among various risk assessment activities is currently under discussion.

QUESTION #11

QUESTION: In FY 1988, $3 million of the funding for reducing the uncertainty of risk assessment was provided by the agency through reprogramming from other areas. Specifically, from where did the $3 million in reprogrammed funds come? What were the effects on these other activities of this reprogramming? Would the funding for these activities be restored in the FY 1989 budget request?

ANSWER: In accordance with an agreement between the Agency and Congress, EPA redirected a total of $3.0 million in FY 1988 into a program for reducing uncertainty in risk assessment. The following identifies activities which were terminated in order to fund the $3 million RURA program. The FY 1989 budget request does not include any funds to restore these terminated activities.

Office	Project	Dollars	Impact
OEETD	PM Control Technology	$125K	Eliminated research on particulate emissions control technology.
OHR	Pulmonary effects of hazardous air pollutants	$275K	Cancelled technical directive on contract for exposures of air toxic chemicals.
OEETD	Upgrading and correcting design deficiencies.	$323K	Cancelled design development on problem technologies, analysis of WPCF, and a manual on POTW's mod.
OEETD	Control of water quality in distribution systems.	$478K	Eliminated math model/ statistics; water quality distribution systems
OHR	Health effects associated with drinking water treatment processes.	$412K	Cancelled task to determine the production of disinfectant by-products *in vivo*.
OHR	Develop methods for identification of pathogenic viruses.	$333K	Cancelled development of Hepatitis A virus detection and assay method.

(#11 Continued)

OEPER	Prediction of environmental concentrations of hazardous wastes--vertical dispersion of hydraulic conductivity.	$490K	Eliminated International Conference on measurement of aquifer physical properties and manual on methods for characterizing physical properties of aquifers.
OEETD	Engineering to control hazardous releases: close OHMSETT and eliminate oil dispersion work.	$300K	Cancelled support to Oil Spill Prevention, Control, Counter measures Program Force; dispersant R&D; Inland/ocean spills of oil and hazardous substances R&D.
OHR	Epidemiology study of Minn. Grain Workers.	$175K	Cooperative agreement with University of Minnesota not funded.
OEPER	Movement and persistence of dioxins in soils and groundwater.	$60K	Will not initiate a project to evaluate dioxin degradation by lignin-degrading bacteria.
OPER	Identification of toxic chemicals in industrial effluents.	$29K	Terminated planned review of industrial effluents analysis for the occurrence of organic chemicals.

TOTAL: $3,000K

QUESTION #12

QUESTION: Is any funding presently available from the EPA for training graduate students in environmental sciences? Does any other agency provide such funding, to EPA's knowledge? Has EPA ever funded such programs? Does EPA share the concern of the Science Advisory Board about the lack of qualified, well-trained personnel in the environmental sciences?

ANSWER: Funding is not presently available for training graduate students in environmental sciences. To our knowledge no other agency funds training for graduate students in environmental sciences.

In the past, EPA has funded graduate studies in environmental sciences through the Congressional add-ons for academic training:

Clean Water	FY'70 - FY'87
Drinking Water	FY'80 - FY'87
Solid Waste	FY'84 - FY'87
Air Programs	FY'70 - FY'87

EPA shares the SAB's concern over the continuing need for such environmentally-trained research technical personnel.

QUESTION #13

QUESTION: What is the Office of Research and Development's research plan for hazardous waste minimization, including in particular work on source reduction?

ANSWER: The Office of Research & Development is planning to conduct the following activities during FY 1989:

- Accelerating and expanding the Waste Reduction Audit Protocol (WRAP) Program that is designed to provide industry with the tools for identifying opportunities for reducing waste generation. Specifically, we are developing industry-specific addenda to the waste audit manual that will make the manual more useful. Also, we are planning to continue developing and field test a training program for auditors.

- Expanding the Waste Reduction Innovative Technology Evaluation (WRITE) Program to include technologies having broad application in industries characterized by smaller companies. We are planning to select projects which involve generic processes thus making the technologies applicable to more than one industry group. The information produced by this Program will be disseminated through the Clearinghouse.

- Establishing the Waste Reduction Institute for Senior Executives (WISE) Program. This program would bring together a group of senior engineers and scientists who have retired from distinguished careers in various waste generating industries that have had strong involvement in waste minimization. We see this institute as a resource to assist smaller and medium sized companies to implement waste minimization programs. They would also act as a support group with great credibility in industry circles for our programs and for waste minimization in general. We believe that by working with a cadre of these people and a trade association we can implement the institute using minimal EPA seed money.

- Compiling information related to waste minimization methods and technology. This information was developed in the course of carrying out the mandates of the Clean Water Act, Clean Air Act, and RCRA. This information would be applicable to and would form the initial data base for the Clearinghouse.

QUESTION #14

QUESTION: EPA's budget request would reduce hazardous waste work by about $3.4 million while increasing Superfund research by $8.4 million. Since the prevention of toxic contamination in the future should be a priority, could you explain this shift from the program that does preventive work to the program that cleans up old sites.

ANSWER: The prevention of toxic contamination is an Agency priority. The shifts of funds between the hazardous waste and Superfund programs in 1989 reflect a phase down of time sensitive programs in hazardous waste and the establishment of two new programs in the Superfund program.

The $3.4 million reduction in the hazardous waste program results from the following actions. First, the Agency's decision not to request funding for the Tufts University Center for Environmental Management in FY 1989 (-$2.8 million). This Center has been funded by EPA since 1983. Because the Center is now fully established, the Agency believes it should seek continued funding on a competitive basis. Second, the Agency will be phasing down engineering evaluations for Best Demonstrated Applicable Technology (BDAT) in support of the land disposal restriction program (-$0.3 million). Finally, the Agency decided to shift 8.1 workyears from hazardous waste to Superfund to help manage project demonstrations being conducted under the new Superfund Innovative Technology Evaluation (SITE) program (-$0.3 million).

The increase of $8.4 million in the Superfund program resulted from an expansion of research on the use of biological degradation (biosystems) at site cleanups ($4.1 million), establishment of a Superfund Innovative Technology Evaluation (SITE) information clearinghouse ($0.5 million), increased project management for the SITE technology demonstration program ($0.5 million), and costs necessary to provide equipment for the Test and Evaluation (T&E) Facility in support of the SITE program at Edison, New Jersey ($2.4 million). The remainder reflects increased costs associated with the 17 additional workyears requested in the Superfund research budget for FY 1989.

QUESTION #15

QUESTION: Are there significant opportunities for reducing hazardous waste R&D costs by collaborating with research organizations in Europe and the Pacific? Would an expanded program of research collaboration enhance the trade position of U.S. companies for exporting hazardous waste treatment technologies?

Answer: There are significant opportunities for reducing hazardous waste R&D costs by collaborating with research organizations in other countries. We have, in the past, worked with a NATO-CCMS group involved in the evaluation of innovative waste disposal technologies in European countries. The Agency is also participating on the Working Group for Hazardous Wastes of the International Solid Wastes and Public Cleansing Association (ISWA). We have been active in the establishment of the Pacific Basin Consortium for hazardous waste disposal. The EPA Hazardous Waste Research Committee will be joining as a member of this consortium. The group will identify projects of interest to the various member countries which will demonstrate new disposal techniques. By obtaining the data from such projects, which would be funded by others, we will be able to leverage the available R&D resources.

An expanded future program of research collaboration would enhance the exposure of available and successful U.S. technologies. The collaboration could also provide valuable export contacts for the U.S. companies that were involved in this program.

QUESTION #16

QUESTION: What has the Superfund Innovative Technology Evaluation (SITE) program accomplished? What have been the principal difficulties encountered in setting up the program? Are the technologies presently being evaluated or demonstrated likely to have a significant impact on actual Superfund cleanups? What obstacles exist that may prevent these new technologies from being used?

ANSWER: In calendar year 1987 and early 1988 (through mid-April), six demonstrations were completed (Shirco electric infrared [1 and 100 ton per day units], Hazcon stabilization/ solidification, American Combustion oxygen burner, Terra Vac vacuum extraction, and International Waste Technology/Geocon In-situ stabilization/solidification). Another demonstration is planned for September, 1988--the DETOX Industries biological process at the United Creosote Superfund Site in Conroe, TX.

Twenty-eight treatment technologies are currently in the program: eight thermal, eight stabilization/solidification, seven biological, four physical, and one chemical. Also, twelve proposals are being evaluated in the emerging technology program (proof of concept development/ evaluation).

The Phase I of the SITE Clearinghouse was started in December of 1987 with a Hotline, Electronic Bulletin Board and Library reference system. Phase II development of fully searchable databases is underway. Abstracts of these databases will be available via the Electronic Bulletin Board.

The SITE 003 solicitation was completed with thirty-one applicants. Of these, six technologies were accepted (included in the twenty-eight, above) and seven were "conditionally accepted" pending submission of additional technical data. Finally, the first SITE Report to Congress was released on May 20, 1988.

The principal difficulties encountered in setting up the program have been: lack of developer-supplied data to support technology claims; lack of developers able to support demonstration costs; difficulty in matching narrowly focused technologies with sites; and for non-Superfund test sites, obtaining permits.

The technologies presently being evaluated or demonstrated are likely to have a significant impact on actual Superfund cleanups. Currently, we are trying to solve some of the most difficult Superfund problems such as funding permanent, on-site, efficient and cost-effective treatment technologies. The SITE program has a good mix among the principal types of treatment technology categories presently. For example, the stabilization/ solidification category has eight technologies varying from

(#16 continued)

cement-pozzolan to silicate macroencapsulation to asphaltic/ reagents, to in-situ plant mixing. Finally, we are evaluating various extraction technologies such as vacuum filtration, critical fluid separation and physical separation.

The obstacles that may prevent these new technologies from being used are: lack of developer capital to continue in the demonstration phase; pollution liability insurance and the risk of technology failure; the uncertainty of whether the technology will be appropriate for a range of sites; and informational impediments regarding the demonstration results to the people who will choose and evaluate cleanup technologies.

QUESTION #17

QUESTION: What is the Office of Research and Development doing to ensure that the information being released under Title III of Superfund will be presented in an accurate, accessible, and understandable way?

ANSWER: The Office of Toxic Substances (OTS) and the Office of Solid Waste and Emergency Response (OSWER), together with the EPA Regional Offices, have lead EPA responsibility for SARA Title III/Prevention programs. OTS is responsible for the Toxic Release Inventory (TRI), the EPA data base of annual chemical emissions from manufacturing facilities that was established by SARA Section 313. OSWER is responsible for the other elements in Title III dealing with emergency planning as well as chemical accident prevention. The Office of Research and Development (ORD) has been working with these organizations to develop an Agency-wide approach that defines who will respond to questions about these programs and what interpretive information the Agency will provide to the Regions and states to distribute.

Currently an ORD total of $350,000 is directed at Title III--$100,000 on improving and documenting techniques for estimating annual emissions as required by SARA Section 313 and $250,000 on air-related technical assistance.

QUESTION #18

Question: Does EPA's money for research on Superfund and Leaking Underground Storage Tanks (LUST) come from a self-financing fund?

Answer: The Superfund and Leaking Underground Storage Tank (LUST) programs, including research and development functions, are funded through two trust funds, the Hazardous Substance Superfund and the Leaking Underground Storage Tank Trust Fund, respectively. For Superfund, the Internal Revenue Service (IRS) collects excise taxes on petroleum and certain chemical feedstocks as well as an environmental tax based on the corporate alternative minimum taxable income (AMTI) as the primary revenue source. In addition, an appropriation from the General Revenue is authorized to the Superfund. Cost recoveries and other miscellaneous receipts are deposited directly into the Hazardous Substance Superfund.

The LUST Trust Fund is financed through a 1/10 of a cent tax on gasoline and other motor fuels including, diesel fuel, and fuels used in aviation and in commercial transportation on inland waterways. Amounts available in the fund in excess of current expenditures are invested by the Secretary of the Treasury in interest-bearing public debt securities. Collected by the IRS, the Fund is expected to accumulate $500 million over 5 years.

Question: Has all of the money due to that fund been collected?

Answer: The taxation mechanisms for both trust funds set forth in the Superfund Amendments and Reauthorization Act (SARA) of 1986, are in place and are enforceable over the 5-year reauthorization period. Current Treasury projections indicate that original tax estimates for both funds are on target. Tax revenues are collected according to IRS regulation and Congress makes appropriations to the Agency from the two trust funds on an annual basis. Additionally, for Superfund, collections from cost recoveries and miscellaneous funds are ongoing and general revenues are appropriated as needed.

Question: Has the Agency requested that all of the money currently collected by the fund be appropriated? If not, then why?

Answer: The 1989 President's budget, as submitted to Congress, reflects the resources needed to meet the Agency's environmental priorities across all appropriations, media and programs.

(#18 continued)

In Superfund, the President's request is designed to address the nation's highest public health and environmental needs associated with abandoned hazardous waste sites and to ensure that statutory cleanup mandates are met. The resources requested represent a balanced effort among the major program functions, including removal and remedial cleanup activities, enforcement, research and development, and management and support. Superfund is an expanding program. Due to the pipeline nature of Superfund cleanups where the final stage, cleanups, is by far the most expensive, prudent fund management dictates that some funds be held in reserve to prepare fot the higher expenses and for when more cleanups are performed.

The LUST program is intended to be a State-lead program. At present, the States are building and developing their capabilities to implement all aspects of the program. Agency requests have reflected this fact and are expected to increase as States move from program development to actual implementation.

QUESTION #19

QUESTION: What is EPA doing to implement the technology transfer provisions of the Stevenson-Wydler Act? Does EPA need new authority to carry out an effective technology transfer program?

ANSWER: EPA has taken a number of steps to implement the Stevenson-Wydler Technology Innovation Act, as amended by the Federal Technology Transfer Act of 1986. We are now completing the implementation documents that set forth the framework within which the directors of all of EPA's government-owned, government-operated laboratories will be allowed to enter into cooperative agreements and licensing agreements under Section 11 of the Act. These documents include a broad delegation of authority, establishment of a review process, and establishment of specific guidelines for the apportionment of royalty income within the broad limits set forth in Section 13 of the Act. In the meantime, we have advised the relevant officials that they are welcome to develop cooperative agreements which can be executed by the Administrator in advance of the formal delegation. We have not yet entered into any cooperative agreements but several proposed agreements are under active negotiation.

The Office of Research and Development has assigned a senior staff member to represent the Agency in the Federal Laboratory Consortium. Recently, a Technology Transfer Advisory Committee has been established within the Office of Research and Development with representatives from all research laboratories and headquarters research and development offices to address technology transfer issues. Also, the Agency is establishing a national advisory council for environmental technology transfer with representatives from business and industry, from the academic, educational and training communities and from Federal, State and local governments. The council will advise EPA on how to accelerate cooperation in the development and commercialization of new technology needed for the United States to achieve its environmental protection goals. Finally, we are providing funding to the National Environmental Technology Applications Corporation, a university-based consortium with active industry participation, to assist in the development of cooperative ventures for specific environmental technologies and other opportunities for technology transfer.

As for new authority, we have advised the Chairman of the House Subcommittee on Science, Research and Technology of the Committee on Science, Space and Technology, and the Chairman of the Senate Committee on Commerce, Science and Transportation of the following concerns: We would like to clarify whether the Section 11 authority to enter into cooperative agreements is an appropriate mechanism for cooperating with non-profit and commercial providers of training in the development and delivery of needed training programs to State and local enviromental per-

(#19 Continued)

sonnel and to private firms in the environmental protection area. If allowable, outside cooperators could provide the needed training on a fee-for-service basis, while allowing payments back to EPA to compensate the Agency for its share of the cost of developing the training.

The amount of computer software developed by EPA continues to increase both in sheer volume and in importance. Outside interest in acquiring and making commercial use of this software is also increasing. Our current inability to copyright software means that the potential commercial benefits of such software are lost. We believe this prohibition should be removed. Current provisions of the Freedom of Information Act appear to apply to new data of commercial value that might be developed by outside cooperators under the provisions of the Federal Technology Transfer Act while these same data would be considered proprietary if generated wholly within the private sector. This situation results in an unnecessary and undesirable restriction of the range of possible cooperative efforts which we believe could be rectified with limited changes to the Freedom of Information Act.

QUESTION #20

QUESTION: Does EPA have computer models capable of predicting the consequences of an accidental release of toxics? If so, have these models been validated through comparison to experimental data?

ANSWER: There are commercially available computerized dispersion models and probalistic risk models which have been developed by the private sector, academia, and various government agencies. They have been validated to a very limited extent by comparison with data from the Nevada test site and other experimental studies. These models are useful tools in predicting the consequences of an accidental release of toxics. EPA is aware of these models and is an active participant in their evaluation, refinement and further development.

QUESTION #21

QUESTION: Has EPA benefited from research conducted in the Department of Energy's (DOE) spill test facility at the Nevada Test Site? Will EPA participate in research conducted at this facility?

ANSWER: Although not directly funded by the Agency, EPA has indirectly benefited from research conducted at the Nevada Test Site spill test facility. For example, results of the toxic cloud dispersion model validation tests, and of the spill control and mitigation tests, are of interest to EPA in its spill response programs. Additionally, EPA benefits from its discussions with the Department of Energy, the Department of Transportation(DOT) and the industrial community regarding research projects at the facility. These discussions provide an awareness of ongoing related research in the public and private sector and allow the Agency to avoid duplicating these research efforts.

EPA will continue to be involved in two aspects of the DOE research conducted at the facility. Through an Interagency Agreement with the DOE, EPA is represented on the DOE test advisory panel which evaluates the safety of each test exercise conducted, and is responsible for conducting off-site monitoring in public areas downwind from the facility during test exercises. A memorandum of understanding between EPA, DOE, and the DOT allows EPA the opportunity to conduct research for its own purposes at the Nevada Test Site. EPA has currently proposed toxic release modeling research, as well as remote monitoring research, pursuant to the Emergency Planning and Community Right-to-Know Act provisions of SARA. It is anticipated that such research would make use of the facilities available at the Nevada Test Site.

QUESTION #22

QUESTION: What is EPA doing to evaluate the health risks both to building occupants and maintenance workers that result from exposure to asbestos and asbestos substitute fibers during remediation activities?

ANSWER: After a review of existing health information both the Office of Research and Development and the Office of Toxic Substances are presently coordinating the design of a workshop, to take place in FY 1989, which will bring together national and internationally known experts to evaluate the present state-of-the-art in assessing the health risks of exposure to asbestos and substitute fibers. Recommendations generated from this workshop will be used to plan future research directions in the assessment of asbestos and substitute fiber health risks.

QUESTION #23

QUESTION: On February 28th, EPA released a report, The EPA Study of Asbestos Containing Materials in Public Buildings, that called for a major increase in funding for asbestos research. Has this report been reviewed by EPA Office of Research and Development? How much funding did it propose? Will the administration use this report as the basis of its FY 1990 funding request?

ANSWER: In EPA's Report to Congress on Asbestos-Containing Materials in Public and Commercial Buildings (February 1988), the Agency outlined a variety of proposed studies at a cost of 120 million dollars over the next two to three years period which would help establish an appropriate public and commercial buildings program. These studies would address (a) the efficacy of operations and maintenance (O&M) techniques, removal techniques, and procedures for controlling fiber release; (b) the extent of fiber release associated with "peak exposure" from certain O&M tasks which might disturb the asbestos; (c) prevailing ambient air levels in buildings; and (d) the numbers and types of persons exposed in public and commercial buildings.

After a review of this report, the Office of Research and Development (ORD) has formed a work group to identify the research needs associated with public and commercial buildings. In addition, ORD recognizes that the gradual replacement of asbestos containing material in the construction of new buildings and renovation of old buildings as a result of ban and phasedown will require the Agency to examine substitute fiber materials as well as asbestos. Therefore, research needs in these areas are being examined for the FY 1990 timeframe as well as possible changes in the FY 1989 asbestos research program.

QUESTION #24

QUESTION: Is most of the $1.4 million proposed increase in funding for pesticides related to the need to dispose of certain pesticides that have banned? Is it the view of the Agency that they should be responsible for the disposal of these pesticides? What pesticides research would EPA support if an additional $1.4 million were made available in this area?

ANSWER: Yes, most of the $1.4 million proposed increase in funding for pesticides is related to the need to dispose of certain pesticides that have been banned.

It is not the Agency's position that EPA should be responsible for the disposal of cancelled and suspended pesticides. The Assistant Administrator for the Office of Pesticides and Toxic Substances has testified on a number of occasions that the manufacturer, not EPA, should be responsible for the storage and disposal of banned pesticides.

If the $1.4 million were made available, pesticides research priorities would have to be reevaluated. Therefore, the Agency is unsure how the funds would be used.

QUESTION #25

QUESTION: What is the status of EPA's Radon Mitigation Demonstration and Diagnostics Program? What are the future plans for these programs? Does EPA presently have the funds to begin to demonstrate mitigation techniques on buildings other than single-family residences, such as schools? Is there currently any research being conducted by EPA or DOE specifically on the health effects of radon on children?

ANSWER; Some of the recent accomplishments of the Radon Mitigation Development and Demonstration Program are:

- o demonstrating the effectiveness of soil ventilation techniques (Soil ventilation is now becoming an almost conventional approach for commercial mitigators working on basement homes);
- o initiating development of other, potentially less expensive, radon reduction techniques (Projects underway on sealing, house pressure control, and other low cost approaches); and
- o publishing an extensive technical guidance manual, regarded as the state-of-the-art document on radon mitigation.

Future plans for these programs center on the development of cost-effective mitigation techniques for homes and other structures. We will continue to do research, concentrating on techniques that are potentially lower in cost, and moving into additional geographic regions. We will be updating the pamphlet "Radon Reduction Methods: A Homeowner's Guide" in the fall to include the most recent research findings.

As for non-residential work, the Agency is initiating work to investigate the extent of the radon problem in schools, and to investigate potential mitigation methods. In FY 89, funds will be available to initiate a School Mitigation Demonstration Program.

The potential health effect associated with radon is lung cancer; this health effect is observed in populations over 40 years of age. DOE is conducting research devoted to lung deposition and dosimetry associated with radon progeny exposures, and this research may enable the estimation of radiation dose to children. DOE is also conducting epidemiology studies on radon exposure which includes, where possible, childhood exposures.

QUESTION #26

QUESTION: Could you provide a summary of EPA indoor air pollution research programs being currently conducted or planned? What were the conclusions of the EPA report, Unfinished Business: A Comparative Assessment of Environmental Problems, regarding the need for further research on indoor air pollution? Will this report be used as the basis for EPA's funding request for indoor air pollution in FY 1990?

ANSWER: The ORD indoor air research program emphasizes four major research areas: (1) Source Characterization and Mitigation; (2) Monitoring; (3) Health Effects; and (4) Exposure Assessment and Risk Characterization. Examples of ongoing and planned research in each of these areas include:

1. **Source Characterization and Mitigation**

   - o conducting chamber studies of emissions from indoor materials and products, including unvented combustion sources;
   - o providing guidance to EPA/OAR and the Consumer Product Safety Commission for the selection and operation of kerosene heaters;
   - o testing and evaluating the performance of air cleaners; and
   - o developing models to compare the effectiveness of ventilation, source modification, and air cleaning mitigation strategies.

2. **Monitoring**

   - o developing, testing, and evaluating low cost monitoring devices for measuring indoor pollutant concentrations;
   - o participating in interagency research devoted to characterizing "sick buildings"; and
   - o developing and validating a state-of-the-art indoor air quality model.

3. **Health Effects**

   - o conducting a study of human neurobehaviorial responses to mixtures of volatile organic compounds (VOCs);
   - o assessing the genotoxicity of emissions from kerosene heaters;
   - o studying the potential health risks from exposures to environmental tobacco smoke.

(#26 Continued)

4. Exposure Assessment and Risk Characterization

- o evaluating different approaches to assessing indoor pollutant exposures, and
- o identifying qualitative hazards associated with indoor pollutants.

In its report, Unfinished Business: A Comparative Assessment of Environmental Problems, EPA ranked pollution problems in four risk areas: cancer risk, non-cancer health risk, ecological effects, and welfare effects. Under cancer risk, indoor air pollution other than radon was ranked in the first category of five, and it tied for fourth out of 29. Under non-cancer health risk, it was ranked as having relatively high risk. Under ecological effects, it was not ranked since it does not have any ecological effects. Finally, under welfare effects, it was ranked as a relatively minor problem and was not ranked numerically.

In developing its FY 1990 budget request for research on indoor air pollution, EPA will certainly use the results of the Unfinished Business report along with other evaluations and its best scientific and technical judgment.

QUESTION #28

QUESTION: One of the major Clean Air Act problems is non-attainment of the ozone standard in urban areas. In some cases, non-attainment is the result of a failure of Agency models to accurately predict the effect on air quality of approved State Implementation Plans. Why did these models fail to provide adequate predictions? What is the Agency doing to improve its predictive capabilities in this area?

ANSWER: There are two major types of models now in use: EKMA and AIRSHED. The EKMA model is the simpler one and assumes that emissions from an entire urban area are uniformly mixed. The model is designed to predict changes in ambient ozone as a result of emission precursor changes. The most important inputs needed to apply this model include: the VOC/NOx ratio for the urban area during 6-9 am, levels of pollutants transported into the urban area, emission rates and their variation during the day, and meteorology (sunlight intensity, mixing height) and its variation during the day. Unfortunately, the EKMA model has several problems which are discussed below.

The required data to input into the model is gathered for a number of "model days", that is, high ozone days observed during the last three years, and the assumption is made that the meteorology will be equally conducive to ozone formation in the future. However, the EKMA predictions of VOC control requirements will be erroneously low if the 6-9-am-VOC/NOx ratio is underestimated and/or if the future meteorology turns out to be more conducive to ozone formation. Additional (positive or negative) errors should also be expected to occur when this simple model is used on complex urban atmospheres (e.g. severe ozone problem cities within megalopolis-type regions). Finally, and most importantly, the EKMA predictions, even when correct, will appear to be erroneously low if the VOC emission inventory data have been underestimated. For example, a 40% VOC control requirement predicted by EKMA, will in fact be tantamount to only a 20% emission reduction if the actual VOC emissions are twice as high as the inventoried ones and the control strategy excludes the uninventoried sources.

The more sophisticated AIRSHED model treats urban ozone formation in much more spatial and temporal detail and is designed to predict absolute levels of ozone air quality. This model is the more appropriate one to use for complex urban atmospheres. The most important inputs needed to apply this model are: emission rates during the day and data on transported-in pollutants and on meteorology (sunlight intensity, mixing height, wind speed/direction).

As with EKMA, the required data for the AIRSHED model is gathered for a number of "model days", and, again, the assumption is made that the meteorology will be equally conducive to ozone formation in the future. The AIRSHED predictions on VOC control

(#28 continued)

requirements will be erroneously low if the VOC emission inventories are underestimated and there is no prior testing of the model for the specific urban area considered. If there is prior model testing, it is expected that large disagreements between model-predicted and observed ozone and precursor concentrations will exist, which would reveal the emission errors. If the emission errors are not corrected and, instead, the model is "tuned" so as to force agreement, the prediction errors will persist. As with the EKMA model, errors in the AIRSHED model predictions are caused also by errors in the other input-related factors or by erroneous assumptions.

The most serious estimation mistake of the effect of SIP controls on ozone air quality probably occurs when the VOC emission inventories are underestimated, and control strategies based on EKMA predictions exclude the uninventoried sources. Models underestimate VOC control requirements (and lead to non-attainment) because of human error and natural effects.

In summary, the most important and probable reasons for model failure are:

(a) The VOC/NOx ratio is underestimated; in fact, recent measurements have suggested that VOC/NOx ratio values are somewhat higher than those used to develop past ozone control strategies;

(b) The assumptions used to simplify the models are not valid for relatively complex atmospheres;

(c) Future meteorology turned out to be more conducive to ozone formation than assumed;

(d) The meteorological input to or basis of the model is inaccurate, and

(e) The chemical mechanism used in the model is inaccurate.

Therefore, the most important causes of non-attainment are not necessarily related to the performance of the models but are related to inputs and assumptions used in the models.

In order to improve predictive capabilities, the Agency is sustaining a research effort to identify and measure uninventoried VOC emissions and to reduce inaccuracies in the chemical mechanism, the VOC/NOx measurement, and the meteorological input required by the models. Intensive research efforts are also underway to address the impacts of "background ozone" and "transported-in ozone". Dramatic improvements have recently been achieved in the emissions and chemical mechanism areas, and new efforts are being conducted in the ozone transport and background ozone areas.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

March 30, 1988

OFFICE OF
THE ADMINISTRATOR

Honorable James Scheuer
Chairman, Committee on Science,
Space and Technology
Subcommittee on Natural Resources,
Agriculture Research and Environment
U. S. House of Representatives
Washington, D. C. 20515

Dear Mr. Chairman:

The Science Advisory Board's (SAB) Research and Development Budget Subcommittee has completed its third annual review of the President's proposed budget for the Office of Research and Development and is pleased to transmit copies to you.

The President's proposed research budget for Fiscal Year (FY) 1989 for the Office of Research and Development (ORD) is $375.0 million and 1,848 workyears, and increase of $22.7 million and 17 workyears above the level for FY '88. The proposed budget provides for important research projects and management developments, including a modest expansion of the in-house research capability, a direction strongly encouraged in last year's Subcommittee report and reiterated this year. Much of the proposed overall increase is somewhat illusionary, however, due to reductions in FY '88 appropriated funds and new programs mandated by Congress with no additional resources provided.

In the scope of its inquiry, the Subcommittee examined four general issues: 1) trends in research budget; 2) human resources issues; 3) the need for early problem identification; and 4) 18 specific research programs, serving six separate areas in the Agency.

The demands placed upon the Agency for new knowledge through research continue to grow at a faster pace than the increases in funding. Concern is expressed about the age structure of ORD and the inadequate infusion of junior scientists, a problem which could be alleviated by the institution of training grant programs. Specific proposals are made for mechanisms to improve the Agency's ability to detect potential problems while they are still "over the horizon". Finally, each of the research programs is discussed in terms of the resources recommended to address the program's mission.

The Subcommittee and the SAB Executive Committee believe that the enclosed report adds to the range of points of view that the Administration and Congress should consider in reaching budgetary decisions. Scientists and engineers have a responsibility to present their thoughts and evaluations of the needs for research in the area of environmental science, and we appreciate the opportunity to do so.

Sincerely,

Norton Nelson, Chairman
Executive Committee
Science Advisory Board

John Neuhold, Chairman
Research and Development Budget Subcommittee
Science Advisory Board

cc: A. James Barnes
Vaun Newill
Donald Barnes

SAB-EC-88-024

REVIEW OF THE PRESIDENT'S PROPOSED BUDGET FOR EPA'S OFFICE OF RESEARCH AND DEVELOPMENT FOR FISCAL YEAR 1989

Research and Development Budget Subcommittee

Science Advisory Board

U. S. Environmental Protection Agency

March 1988

U. S. ENVIRONMENTAL PROTECTION AGENCY

NOTICE

This report has been written as a part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide a balanced expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

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I. Executive Summary

The President's proposed budget for Fiscal Year (FY) 1989 for the Environmental Protection Agency (EPA) requests approximately $4.8 billion and 14,570 workyears. Of this total, $375.0 million and 1,848 workyears are requested for research and development, an increase of $22.7 million and 17 workyears above the levels for FY '88 enacted during the recent Bipartison Agreement between the Administration and the Congress.

Approximately $197 million of the proposed research budget is earmarked marked for the extramural (research and development) account, with $110 million devoted for in-house (salaries and expenses) needs. Additionally $67 million is alotted for Superfund work ($56 million extramural, $11 million intramural) and $0.8 million for work on leaking underground storage tanks. The intramural funding level continues the modest expansion of the in-house research capability, a development strongly encouraged in last year's Subcommittee report and reiterated this year.

Some continuing core needs of EPA's research program highlighted in last year's Subcommittee report merit re-emphasis. These include the increasingly diverse skills required to research EPA's growing number of new regulatory and policy priorities, and the need for a more formal mechanism to define emerging public health and environmental problems. For example, at present, the Agency has few researchers with stature in the scientific community who are knowledgeable about the ecological effects of stratospheric ozone depletion. This illustrates the continuing dilemma of EPA's research program having to catch-up to regulatory problems, and needing several years to acquire the requisite talents to formulate creative research programs to address those problems. The 18 programs specifically addressed by the Subcommittee this year are in the Table of Contents.

The Subcommittee recommends that an in-house group be established to identify new (and escalating) ecological and environmental health problems. This in-house group, composed of people from varying scientific and policy-related disciplines, should prepare an annual report of potential new problems and recommend needed research. The group could examine monitoring data, survey literature and conferences; hold workshops: and, prepare scenarios of assumed future social and technological conditions as means of identifying new and rapidly escalating problems.

The Research and Development Budget Subcommittee of the Science Advisory Board is encouraged by the recognition of stratospheric ozone depletion, radon mitigation and Superfund research centers as priorities. In addition, resources are proposed (not as part of the research budget) for upgrading certain technical facilities. On the other hand, much of the proposed overall increase for research is somewhat illusionary because of the general reduction of $15.2 million for the Office of Research and Development in the final FY '88 appropriation, and the new Congressionally mandated program ($3M in FY '88 and $10 million in FY '89--with no additional resources provided) to reduce uncertainty in risk assessment (RURA). The Subcommittee strongly recommends that the Congress appropriate new monies when it adds new requirements for EPA research.

The demands placed upon the Agency for new knowledge through research continue to grow at a faster pace than the increase in funding. This is reflected in comments in a number of areas in this report.

II. Introduction

During the past several years, EPA's research programs have encountered many different challenges. They face the continuing need to provide scientific support for on-going regulatory decision making in EPA's major program areas. At the same time, the research programs are attempting to address newer environmental problems such as global climate change and indoor radon, and to respond to augmented requirements enacted by the Congress through amendments to the Safe Drinking Water Act, Clean Water Act, Resource Conservation and Recovery Act and Superfund. In managing the resources available to it and maintain research productivity, the Office of Research and Development confronts continuing problems in ensuring that it has adequately trained personnel that possess both the skills and the equipment to carry out these responsibilities. The latter area, in particular, has seen a continuing erosion over the past decade such that EPA research facilities often do not possess a state-of-the-art capability to detect or assess environmental problems. Finally, there are notable disparities between EPA's research needs and the resources it has to conduct and/or sponsor research in such areas as incineration technologies, global climate change, land disposal and exploratory research.

Scientists and engineers, of course, have an obligation to help set research priorities to better match needs with resources, but their ability to rationally select priorities is hampered by Congressional restrictions on the flexible use of existing resources, the unpredictability of a budgeting process that leads to constantly changing priorities and the mandating or new responsibilities in the absence of commensurate resources. Despite these difficulties, the President's proposed budget to EPA's Office of Research and Development maintains a commitment to continued funding of certain key research programs. These and other issues are discussed in this report.

This is the third annual report of the Research and Development Budget Subcommittee of the Science Advisory Board. In previous years, the Subcommittee has sought to identify continuing core needs for maintaining productive and high quality research at EPA, while highlighting specific needs for individual research programs. This year's report continues that effort. The current report resulted from a Subcommittee meeting on February 11-12, 1988 at EPA headquarters, in which members received background briefings on the ORD and EPA-wide budget proposal for FY '89. The Subcommittee prepared an initial draft of its findings and recommendations at the meeting and completed its report by mail. Following approval by the SAB Executive Committee, the report was simultaneously transmitted to the EPA Administrator and the Congress.

This report is part of a series of actions in which the Science Advisory Board attempts to improve the quality, direction and support of research at EPA. Other activities include:

o Formation of a Research Strategies Committee (the Alm Committee) to develop a strategy which will identify and communicate to EPA program offices, the Congress, the Office of Management and Budget, the scientific community and the public the research opportunities and needs related to EPA's mission in the 1990's, and to identify mechanisms to continually update such research across media lines.

o Review of individual research programs that in the past year has included land disposal, stratospheric and tropospheric ozone, waste minimization, radon mitigation, drinking water disinfectants and their by-products, pollutants in the water distribution system and municipal waste combustion.

o Evaluation of scientific assessment documents and methodologies for risk assessment that provides a scientific basis for regulatory decision making.

It is the Board's hope that, by presenting these views directly to policy makers in the Executive Branch and the Congress, scientists and engineers can articulate some of EPA's most important research needs and, by doing so, persuade policy makers to allocate the resources necessary to fund research to resolve environmental problems and achieve our common objective of protecting the public health and the environment.

III. Some Generic Issues in Managing EPA's Research Program

A. Research Budget Trends

The total amount of resources available for research and development stems from four major accounts: Salaries and Expenses (S & E—in-house monies available for research, salaries, equipment purchases, and maintenance of scientific infrastructure such as animal care in laboratories); research and development (extramural funds devoted to research grants and contracts); Superfund; and the Leaking Underground Storage Tank (LUST) Trust Fund. For FY '89 the proposed budget recommends the following amounts in each category:

(Dollars in Millions)

Appropriation	1989 Total Dollars	Change from 1988 Level
Salaries & Expenses	$110.4	+$3.7
Research and Development	197.0	+10.6
Superfund	66.8	+ 8.4
LUST Trust Fund	0.8	—
Total	$375.0	+$22.7

The Subcommittee highlights two specific issues related to these budget recommendations. They include:

o Support for the in-house (or S&E) program shows modest yet continued growth in support for the in-house program. As noted above, approximately $3.7 million additional dollars are made available for in-house research. The Subcommittee, as in previous years, supports this trend, but observes it barely meets the cost of living increases.

The Congress can expect that a real expansion of the in-house program will not only improve EPA's internal research capabilities but will also enhance the ability of Agency scientists to interact more effectively with the scientific community and improve their management of extramural (R&D) resources. Such developments, if sustained, should improve EPA's overall research productivity and credibility.

o Growth in the in-house program combined with two other developments, can begin to alleviate one of EPA's major chronic problems--aging equipment and facilities. Beginning last fiscal year the Congress authorized the use of extramural funds of up to $2 million for equipment purchases. This is a welcome step that provides additional flexibility in managing research resources. The problem of obsolescent equipment is becoming acute in certain EPA laboratories. For example, its water research laboratory in Cincinnati currently lacks the instrumentation to identify potentially hazardous chemicals resulting from the by-products of disinfection technologies used as a substitute for chlorination.[1] This occurs at a time when regulations developed by EPA's Office of Drinking Water encourage the shift to disinfection alternatives. A second factor influencing the capability of the in-house program stems from proposed improvements to selected research facilities. Resources (not taken from the ORD budget) are proposed for reconstruction of field stations in Newport, Oregon ($12.2 million) and Edison, New Jersey ($5.6 million), and an architectural and engineering study for the Chapel Hill North Carolina Clinical Facility ($1.7 million). EPA, the Administration and Congress should recognize the relationship between equipment and facility improvement and research productivity. The Subcommittee recommends that the Congress require EPA to prepare a study of scientific infrastructure needs by January 1, 1989 to enable the executive and legislative branches of government to provide sustained support for equipment and facility enhancement. To avoid this responsibility is to witness a deterioration of unique physical assets that serve the national interest.

EPA's research program is subdivided into ten major components, not including resources provided for management and support. The following table present the recommended funding levels for each program category, and the change from the FY '88 appropriation:

(Dollars in Millions)

Research Program	1989 Total Dollars	Change From 1988 Level
Air	$72.5	+$6.7
Water Quality	25.1	+ 0.4
Drinking Water	22.0	- 0.5
Hazardous Waste	41.3	- 3.4
Pesticides	14.4	+ 1.5
Radiation	4.0	+ 1.1
Interdisciplinary	34.2	+ 7.2
Toxic Substances	26.6	- 0.2
Energy/Acid Rain	55.5	- 0.1
Superfund/LUST	67.6	+ 8.4
Management & Support	11.8	+ 1.6
Total	$375.0	+$22.7

Section IV of this report presents the Subcommittee's evaluation of each of these program elements.

B. Human Resource Issues

The Full Time Equivalents (FTE) recommended for ORD, 1,848 workyears, remains approximately the same as the FY '88 level of 1,831 workyears. The Science Advisory Board expresses its concern once again that a human resource problem is emerging in ORD, although its origins do not lie in the overall size of ORD's workforce. Rather, it stems from the fact that the age structure of the organization is becoming top heavy with mid-level managers and an inadequate infusion of junior scientists to meet the demands of attrition and aging. Furthermore, the corps of young people being trained in the environmental sciences has been declining since the mid-1970s to a level where an insufficient supply will emerge to fill the needs of the Agency as its longer tenured scientists reach retirement age or otherwise leave the Agency. The drinking water research program, for example, has lost nearly a half dozen senior scientists in recent years, one of whom was a member of the National Academy of Engineering. This represents significant reduction for this particular research group and is only one instance of a broader problem.

Congress and the Agency could avoid a potential crisis in this area by instituting training grant programs at the universities, much as was done in the 1960s and early 1970s. Based on enrollments in environmental programs, shortages will exist in environmental engineering, chemistry, ecology, and epidemiology. Training programs implemented now will produce trained people within three years, in time to avoid a crisis.

At the same time EPA confronts this problem, it has an apparent over-supply of mid-level research managers that it is seeking to assign elsewhere. The Agency needs to find ways to effectively use the accumulated skills

of these managers. To date, it has sought to voluntarily relocate mid-level technical staff to EPA regional offices. For FY '88 ORD has assigned personnel in three regional offices and plans to expand this career alternative to all ten regions. The Subcommittee endorses this approach, for it can simultaneously improve the scientific capability of the regional offices and create opportunities to bring younger people with new skills into ORD headquarters and laboratory programs. This alternative alone is unlikely to solve this ORD problem.

C. Early Problem Identification

As discussed in the Subcommittee's review of the FY '88 budget, early identification of potential emerging and escalating environmental problems should take its place along with risk assessment and risk management as a central part of EPA's mission. The proposed research budget provides no funds specifically earmarked toward this objective. This is disappointing in view of the number of issues--such as radon, stratospheric ozone depletion and global climate change--that have only recently risen to the top of EPA's policy agenda but which were known to the scientific community for a number of years. It is also surprising because of the relatively high risks and the rising priority for those "newer" problems discussed in EPA's February 1987 report entitled Unfinished Business: A Comparative Assessment of Environmental Problems. While admittedly not a scientific study, this report provides a rationale for follow-up investigations that need to be pursued, if only to minimize future surprises and ensure that resources are better matched to significant sources of public health and environmental risk.

The Subcommittee recommends that an in-house group be established to identify new ecological and environmental health problems, with input from many outside sources so the in-house group does not become too inbred in its thinking. This group, composed of people from varying scientific and policy-related disciplines, should prepare an annual report of potential new problems and recommend needed research. The group could survey existing literature and prepare scenarios of assumed future social and technological conditions as a means of identifying new problems. This effort also needs the participation of external experts. One mechanisms is to utilize the National Academy of Sciences to assist in marshalling leading scientists, engineers, sociologists, and others to participate in a series of workshops to identify potential and emerging ecological and health stressors. Such participation would require new money.

The need to identify problems also requires international cooperation. The increased internationalization of technology and trade also creates environmental problems that transcend national boundaries. There is a need to work with Canada concerning acid deposition and Great Lakes water quality.

There is a need to work with Mexico on water quality degradation of the Colorado River water in Mexico due to U.S. agricultural discharges and air quality degradation in the U.S. due emissions of a very large Mexican copper smelter. The saga of the barge carrying Islip, New York and New York City's commercial solid waste up and down the east coast and around the Carribbean Sea demonstrates that problems previously regarded as domestic are international in scope. On an even larger scale, the issues of stratospheric ozone depletion and global climate change require greater integration among scientific assessment, policy analysis and mitigation efforts that any previous environmental problems to date. It is particularly important for the U.S. government to maintain a capability to evaluate the magnitude of these issues and to identify others like them.

IV. Comments on Specific Research Programs

The Subcommittee has evaluated the research budget proposals in each of the major program categories. The Subcommittee prepared its comments by examining the rationale contained in budgetary documents that justify funding increases or decreases, and compared this rationale to the conclusions of SAB reviews of research programs conducted in the past year. The expertise of Subcommittee members was also a primary source of information for preparing the following comments.

A. Air and Radiation

1. Criteria Air Pollutant Research

The proposed decrease in FY '89 funding on research in support of criteria pollutants (National Ambient Air Quality Standards, or NAAQS) reflects the fact that the effects of such pollutants are more widely understood in comparison with many other problems confronting EPA. However, there remain many unresolved technical issues for NAAQS, which are among the most costly regulations developed by EPA. This Subcommittee focused, in particular, on needs related to short-term effects of nitrogen dioxide and chronic effects of ozone. For nitrogen dioxide, the Agency has not supported the research needed to enable it to meet the Congressional mandate to either set a short-term NAAQS or to demonstrate that one was not needed. For ozone, the SAB's Clean Air Scientific Advisory Committee research recommendations call for greatly increased emphasis on the effects of chronic exposure on lung structure.[2] This extremely important aspect of ozone health effects has received too little attention in the past and will need augmented research funding to generate the data base needed for a policy decision on whether to establish a long-term ozone standard. Given the fact that a major fraction of the U. S. population lives in areas of the country that do not attain the current ozone standard, ozone exposure will remain a high priority issue for many years to come.

The proposed FY '89 budget also does not address another need for research on criteria pollutants, i.e., the health effects of acidic aerosols. The recent issues paper prepared by ORD and the Office of Air Quality Planning and Standards provides evidence of the rising importance of this issue. The Agency will need much more data on the nature of population exposures and responses as it moves to evaluate whether to consider a new NAAQS for these pollutants.

2. Air Toxics

The $1 million decrease in research funding for hazardous air pollutants proposed for FY '89 is troublesome in view of the potential impacts such pollutants can have on human health, the dearth of data on current population exposures and the need for more reliable risk assessment methodologies. In the absence of sufficient resources to support a new emphasis on exposure and effects assessment, and on the nature and impact of sudden massive releases of chemicals to the environment, the current emphasis on risk assessment is appropriate.

3. Indoor Air Pollutants

The 14% increase proposed for FY '89 for research on indoor air pollutants will permit a significant expansion of the Agency's ability to communicate risks to the general public based on current knowledge concerning health effects and control resources. However, it will only begin to provide a basis for the substantial increase in the knowledge base which is needed.

4. Stratospheric Ozone

The signing of the Montreal stratospheric ozone protocol by the United States and other nations represents a major international achievement. Embedded within the protocol is a commitment to initiate scientific assessments of the ozone depletion problem in 1990 and 1994. There is a wide recognition within the scientific communities of many nations, including the United States, that more research is needed to better establish the scope of the human health and environmental effects of concern and the levels of Ultraviolet-B (UV-B) radiation exposure at which they occur.

During its review of the EPA document, An Assessment of the Risks of Stratospheric Modification, the Science Advisory Board's Stratospheric Ozone Subcommittee concluded that "the potential impacts on aquatic and terrestrial food chains, and the potential effects on the equilibrium of plant and animal assemblages, are just as important as the more intensively studied human effects."[3] Subsequent to that Subcommittee's transmittal of its report, the Office of Management and Budget solicited its further advice on research needs and priorities.[4] Subcommittee members responded by proposing research that focused on a number of endpoints, particularly aquatic and plant systems.[5]

The FY '89 budget proposal provides a substantial increase of approximately $7 million for stratospheric ozone research. The program will focus upon such issues as assessing the effects of ozone depletion upon plants, marine ecosystems and air quality. The Research and Development Budget Subcommittee welcomes this commitment to a vigorous research program and recommends that it continue over a series of fiscal years because of the continuing domestic and international policy decisions for which research support is needed.

5. Global Climate

The issue of global climate change is likely to be even more complex than stratospheric ozone depletion as a scientific problem and in terms of the policy issues requiring resolution. In recognition of this, nations such as the United States and the Soviet Union, as well as the United Nations, are beginning a more formal process of scientific evaluation of this problem. Thus, the need for a well-designed, funded and sustained research program to address the host of interlinked scientific and policy questions related to global climate change is compelling.

Therefore, the $493 million increase in EPA's proposed FY '89 research budget for this problem is welcomed. The Subcommittee supports this increased funding and suggests that new resources at least equivalent to those earmarked for stratospheric ozone depletion should be made available.

The Subcommittee also recommends that EPA prepare a research plan to demonstrate its capability to wisely use additional resources, and that such a plan should identify research needs for a period of at least a decade. External scientific experts should be called upon to assist in preparing and reviewing such a plan.

6. Radon Mitigation

Last year, the President proposed a major reduction in funding for radiation research with most of the decrease taken from the radon mitigation program. In last year's report, the Subcommittee concluded that, as a result, "The radon mitigation program cannot achieve its previously stated objectives of developing and publishing acceptable mitigation techniques that will apply to the variety of problems facing American homeowners."

The FY '89 proposal recommends an increase of approximately $1 million for radon with the majority of funds devoted to demonstration and evaluation of techniques to prevent and mitigate radon in homes, and to analyze the results of such efforts.

The Subcommittee applauds this change. The SAB's Radiation Advisory Committee has maintained a continuing scientific oversight of this research program and is favorably impressed with both the quality and direction of EPA's efforts to date.[6] The proposed increase should solidify and enable EPA to build on the progress achieved to date.

The proposed radiation research budget also includes funds for radiological monitoring and surveillance services for the Department of Energy's Nuclear Testing Program, and a radiochemical analytical quality assurance program for making radioactivity measurements at Federal, State and local laboratories. Both of these programs merit continued support.

B. Water

1. Water Quality

The proposed budget for water quality research increases $347,000 for a total of approximately $25 million. In addition to continuing with research on water quality criteria and standards, developing use attainability analyses and implementing water quality based standards, and the Great Lakes, the Agency proposes research on the problem of the loss or degradation of wetlands.

With the support of the scientific community, the trend in water quality criteria development and standard setting has evolved towards a regional framework, based upon the recognition of region-specific environmental needs, and using geological and ecological principles. The Subcommittee endorses the Agency's recognition of the need for furthering the ecoregion approach, but it believes that, with additional resources, many more important scientific insights can be obtained.

In its FY '88 budget report, the Subcommittee commented on the need to begin to focus attention on non-point water pollution sources. ORD has initiated the planning of research efforts into sediments, which are a latent source of pollutants and which cannot be attributed to a single source. Because of the huge impact of non-point sources on water quality, this effort should be seen as only the beginning of a research program that should also address non-point inputs from surface runoff and direct atmospheric sources.

The important area of ground water research receives approximately a 1% increase over the FY '88 budget, or $76,300. Since much of the Nation's water supply comes from groundwater sources, it is imperative that the assessment programs proposed on sources, transport, transformation of groundwater contaminants be emphasized.

2. Drinking Water

The proposed FY '89 research funding of $21.9 million represents a 2% reduction below FY '88 levels and about a 4% reduction below the FY '87 appropriation.

This past year the SAB Environmental Health Committee reviewed three major drinking water issues: research on drinking water disinfection and disinfection by-products'; research on pollutants in water distribution systems;[7] and a review of the scientific data base for the proposed rules for surface water treatment and coliforms.[8]

There is a growing recognition among scientists, engineers, governmental officials and water supply providers of the public health risks associated with the continuing incidence of waterborne disease, and the increasing need to investigate the public health implications of the use of alternative disinfection techniques and their by-products.

At present, EPA's disinfection work is almost wholly focused on chlorination and chlorination by-products. More attention should be devoted to the potential toxicity problems that could arise from alternatives and/or adjuncts to chlorination such as chloramination, and the use of ozone, chlorine dioxide and other disinfectant processes. As treatment systems turn to the use of alternative treatment approaches, it is necessary to expand the research focus to determine which treatment methods protect public health most effectively, and to compare the relative effectiveness and risks associated with each treatment technology. Microbiological research in water systems is also an area that merits additional support, particularly studies of assimiliable organic carbon which may be used as an indicator of growth or absence of growth of microbiological contaminants in water distribution systems. Lack of funding seems to be the basis for reduced work on corrosion. This is short-sighted because there are a number of unresolved scientific and policy issues related to the public health threat posed by the leaching of lead and the corrosion of asbestos pipe. For all of the above reasons, the proposed budget of approximately $3.3 million for the disinfection by-products and water distribution system programs should be greatly increased.

C. Hazardous Wastes/LUST/Superfund

The large economic commitment of the United States toward proper management of hazardous wastes and remediation of existing waste sites warrants the development of a sound scientific basis to ensure that clean-up efforts are both cost-efficient and effective. The combined hazardous waste/LUST/Superfund research program in FY '89 shows an increase of $5 million above FY '88 levels, for a total of $108.9 million.

1. Superfund Innovative Technology Evaluation (SITE)

The SITE program, which evaluates new remediation technology largely on a demonstration scale, is budgeted at $20 million for FY '89, not including cost-sharing by industry. Approximately $1 million is earmarked for emerging technology and another $1 million for monitoring method components. At present, there are 22 SITE projects underway. The Subcommittee believes that the SITE program has made steady progress since its inception and can effectively use the recommended resources.

2. Waste Minimization

Preventing or reducing the generation of wastes is important for many reasons. These include: a) pollution control technologies are not 100% reliable and some releases inevitably result; b) some control technologies transfer contaminants to different environmental media and create new environmental problems; and c) siting new waste management capacity is very difficult, if not impossible.

Although a few companies and a few states have aggressively pursued waste minimization, many have not. Interest in waste minimization is growing, however, as evidenced by an expanding number of reports, conferences, and legislative proposals devoted to this subject.

Waste minimization deserves substantial visibility and commitment at the highest levels of EPA. Although the Agency has made some progress in its awareness of the need for waste minimization, its current programs and budgets are far too limited to realize the potential benefits. In part, this reflects the difficulty EPA has concerning its role as a pollution "prevention" agency.

In a review of EPA's waste minimization research strategy, the SAB's Environmental Engineering Committee concluded that it should encompass a variety of on- and off-site, in-process, and post-generation waste management options that reduce the hazard of a waste, including waste treatment.[9] The Committee recommended that EPA's waste minimization program could initially focus most productively upon waste prevention (source reduction) and waste recovery/reuse/recycling. The Committee agreed that waste prevention is the most desirable option. It is the option that the Agency's waste minimization program should strongly emphasize, but which has not been directly supported to date. From a practical standpoint, however, EPA may choose to include waste recycling and reuse in the program because, in many instances, this option will provide economic benefits to waste generators. The waste minimization research program should not include waste treatment because it is already addressed by other research programs.

Initially focusing the program on hazardous waste prevention (source reduction) and recycling was reasonable. The goal of the program, however, must remain protection of human health and the environment, rather than changes that merely result in avoiding the regulatory classification of a "hazardous waste."

Given these and other substantial research opportunities, the FY '89 budget proposal seriously underfunds the most promising opportunities to reduce the Nation's hazardous waste disposal problems. The program could effectively utilize double or triple the recommended level of resources.

3. Land Disposal

Although not widely acknowledged, land disposal must continue to be an integral part of the nation's waste management strategy. Other waste management options exist and should be used, but land disposal has a continuing, inevitable, and important waste management role for EPA and for the nation.[10]

EPA needs a strong and continuing land disposal research program to address such important issues as: a) the land disposal of ash from the incineration of hazardous and municipal solid wastes, very small quantity generator wastes, residues produced by best demonstrated available technology (BDAT) treatment of hazardous wastes, and large volume wastes; b) the proper design of Subtitle D facilities, including municipal landfills and industrial non-hazardous waste landfills and surface impoundments; and c) appropriate methods for the closure and post-closure

care of hazardous and non-hazardous landfills, surface impoundments and waste piles.

There is a need to evaluate and understand the long-term performance of what are now considered environmentally sound land disposal practices and the associated monitoring methods to assure that these practices are environmentally sound over many decades.

These needs are not recognized by the Congress and the EPA, and EPA does not have a waste management strategy that defines the continuing role of land disposal. Unless this is corrected, EPA and the nation will lack the scientific and technical knowledge necessary to the ongoing development of scientifically sound land disposal guidance and regulations. Congress and the EPA should provide adequate support for the Land Disposal Research Program so that it can continue to provide land disposal data and information and develop a mechanism so that individual shifts in Agency-wide priorities do not leave it devoid of an important capability. The proposed budget of $2.5 million to support implementation of land disposal regulations essentially maintains the level of funding from the previous fiscal year. It also delays the Agency's capability to respond in a scientifically responsible manner to the growing number of land disposal-related problems that confront it.

4. Municipal Waste Combustion

The technology of municipal waste combustion has emerged as a major alternative to land filling for solid waste disposal in a number of urban areas. A number of scientific uncertainties, however, are associated with this technology including the characterization of emissions, including metals, from existing combustor stacks; identification of the products of incomplete combustion; ash disposal; determination of the transport, transformation and fate of emissions; exposure assessment and potential risk to humans and ecosystems.

In the past year, ORD has prepared a municipal waste combustion research plan. A SAB Subcommittee has reviewed the plan and concluded that because of budgetary constraints important areas are either omitted (such as evaluation of ecological effects) or are addressed in a superficial fashion.[11]

The FY '89 budget proposal includes $2.5 million for research on municipal waste combustion that will support efforts to develop emissions standards. This will enable ORD to conduct emissions tests at some existing facilities and to research various ash disposal techniques such as solidification. These represent important research needs, but they will not, taken alone, resolve the host of scientific questions and public concerns surrounding the siting and use of this technology. As a result, controversy and lack of public confidence in EPA decision making will persist, making it increasingly difficult to solve the nation's municipal waste disposal problem.

D. Pesticides/Toxic Substances

Research funding for pesticides and toxic substances in the FY '89 proposal has increased over the FY '88 appropriation. Individual research programs change also within the overall ceiling. An increase of $1.4 million addresses pesticide research for destruction and disposal of pesticides that have been cancelled and suspended under FIFRA. Resources have been decreased by $322,600 for development of asbestos monitoring and control technologies, a program scheduled for Science Advisory Board review later this year. A re-examination of the risks involved with the various alternatives for management of the asbestos problem is needed before major expenditures on removal and reconstruction is mandated by Agency rules.

1. Superfund Amendments Reauthorization Act (SARA) Title III Research (community right-to-know)

No new research monies were allocated in support of SARA Title III, although releases to the environment and inventories of chemical stocks in process will become public knowledge beginning in the last half of 1988 for several hundred chemicals handled in certain industrial categories. Congress should expand EPA's resources devoted to the development and interpretation of information on these chemicals in a form that can be communicated in response to questions from the public.

2. Biotechnology

Resources for biotechnology and microbial and biochemical pest control agents have remained at essentially at the same level since FY '87, or approximately $6.9 million ($4.1 in toxics, $2.8 in pesticides).

The Biotechnology Research Review Subcommittee of the Science Advisory Board has just completed a review of the Office of Research and Development's Biotechnology/Microbial Pest Control Agent Risk Assessment Research Program.[12] The major recommendation of the Subcommittee is that EPA redefine its focus to emphasize three areas: 1) investigating and analyzing environmental effects, 2) developing control strategies for containment and mitigation, and 3) refining further applications such as protocols, microcosms, models and field tests. In light of the significant accomplishments of the program to date, primarily in developing methods for enumeration, identification and protection, the continuity in funding should enable this shift in focus to be made. Research is also recommended for determining the potential for environmental change that may result as genes may transform naturally occurring organisms.

3. Adipose Tissue Bank

The Agency currently plans to drop this non-ORD $2 million program because of budgetary constraints. In the past, it has served as

an authoritative source of information on the accumulation or reduction of chemicals in the human body. It has reported, for example, the declining levels of polychlorinated biphenyls in human fat. The Subcommittee believes there is a national interest in maintaining the program. Whether samples need to be collected and analyzed on an annual or other basis should be formally evaluated by EPA in a report that should be submitted to the Congress. EPA should consider, for example, whether it is technically feasible or desirable to conduct periodic assessments similar to the National Health and Nutrition Evaluation Survey (NHANES).

E. Interdisciplinary Research

1. Reducing Uncertainties in Risk Assessment (RURA)

Research to support risk assessment is a primary function of ORD programs. Over the past several years Congress, the Science Advisory Board and EPA have recognized the need to modify or initiate research projects into a conceptual framework whose integrating theme is risk assessment. In the FY '88 Bipartisan Agreement, Congress mandated the establishment of a $10 million research program to reduce uncertainties in risk assessment (RURA) but provided no new monies to conduct the research. This requirement has added considerable budgetary uncertainty to the task of reducing scientific uncertainty. EPA research managers, beginning in the summer of 1987, have invested enormous amounts of time planning scenarios to cancel or redefine existing productive research projects into order to conform to the budgetary requirements of RURA.

The FY '89 budget proposes an increase of $7 million for this effort ($3 million in FY '88) for a total of $10 million. Since this increase results from the diversion of funds from other program categories, it is somewhat illusionary. To date, EPA has developed plans for defining priority research areas under RURA and prepared criteria for selecting projects. The plans and objectives for the RURA program might be usefully reviewed by the Science Advisory Board or another external peer review body.

The Subcommittee believes that research to reduce risk assessment uncertainties is a vital Agency-wide need. However, Congress mandated the program and the forced manner that EPA must adopt to ensure compliance with the Congressional objective does not give the Subcommittee a high level of confidence that good science will be produced. Changes of this magnitude often require a change in skill base and sudden changes can be disruptive to people and expertise now in place.

2. Exploratory Grants and Centers Program

Many of EPA's recent crises or priorities are issues for which there exists no consistent background research generated by ORD. These issues include, for example, stratospheric ozone depletion, the incineration of municipal solid and industrial chemical wastes, and residential radon exposures. Scientists have long-recognized the importance of these and other issues, but their efforts did not receive the necessary support, in part because they were not immediate regulatory priorities.

Many of these unanticipated issues have been addressed in research proposals prepared by scientific investigators at EPA funded academic centers and in individual research grant proposals submitted to the Office of Exploratory Research. Peer reviewers have judged these proposals to have scientific merit. Investigator-initiated research under the Grants program is predicted on the sound assumption that the scientific community has valuable ideas as to what needs to be done and has a good chance of providing information of an innovative nature. Unfortunately, the levels of financial support available for these proposed projects has been much too low for the past five years, and only a small fraction of the highly regarded and highly relevant proposals have been funded. This accounts, at least in part, for the lack of relevant data for decision makers where "new crisis issues" emerge. This development will continue to hobble EPA's ability to respond to new problems until a means is found to adequately fund research beyond the immediate regulatory needs. The proposed FY '89 budget fails to remedy the inadequate level of support for research grants.

The Congress has mandated that a portion of the Superfund research program be directed to the establishment of five centers for the exploration of hazardous waste site impacts. The FY '89 budget proposes approximately $5 million for these centers, or a level of about $1 million per center per year. This amount should provide a critical mass of resources necessary to attract qualified proposals from the university community and should lead to a productive research program. EPA should widely solicit research proposals for these centers (which will be managed by ORD's Office of Exploratory Research) and make the final selection on an independent, peer reviewed and competitive basis.

It is unfortunate that EPA's existing research centers, which were established to meet needs in areas as diverse as ecology, ground water, epidemiology, and control technology are being funded at levels deemed marginal by the scientific community. The Science Advisory Board, for example, has several times in the past recommended that the average funding level of these centers be increased from their current average of $540,000 to a minimum of $800,000 - $1,000,000 per center. In view of the FY '89 funding proposal for the Superfund centers, and the productivity of the existing centers program, the Administration and the Congress should adopt a policy of parity and appropriate $1 million for each of the existing centers.

F. Multi-Media and Energy Research

1. Acid Deposition

The ten-year research program mandated by the Acid Precipitation Act of 1980 is reaching closure, and this is reflected in the leveling off of funding for acid deposition research. From FY '87 to FY '88 EPA's program sustained a reduction of $3 million, while proposed funding for FY '89 remains even at $52 million, out of a total Federal research

budget of approximately $83 million. EPA assumes that, by the end of FY '90, two thirds of the projects in the existing acid deposition research program will be completed.

The Subcommittee has two reactions to this evolution of events. First, it has supported a consistent funding base for acid deposition research because of the large scientific uncertainities and large societal costs associated with mitigating this environmental problem. Second, many other research priorities have emerged that also merit research support.

Under almost any set of assumptions, funding for acid deposition research will change and/or decline. The rate and direction of change should consider several factors. These include:

o Much of the acid deposition research is linked to other environmental problems. The lake and stream surveys for example, provide a baseline for future research on these sensitive ecosystems.

o Development of monitoring programs provide a capability, if continued, for establishment of "early warning" systems to detect ecological changes, and longitudinal analyses of acidic flux.

o The acid deposition program can provide a scientific basis for a transition to a broader "ecosystems" research effort that could be used to better define sensitive ecological endpoints, develop and verify ecological risk assessment methods and evaluate ecosystem productivity.

The Subcommittee recommends that EPA prepare a research plan to identify options for the future role of acid deposition research and its relationship to other environmental research problems and opportunities. At the same time, Congress should support the level of funding proposed in the FY '89 budget.

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RESEARCH AND DEVELOPMENT

IN THE

FY89 EPA BUDGET PROPOSAL

Prepared for the Use of the

House Committee on Science, Space and Technology
Subcommittee on Natural Resources, Agricultural Research
and the Environment

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April 15, 1988

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RESEARCH AND DEVELOPMENT PROGRAM IN THE FY89 EPA BUDGET PROPOSAL

SUMMARY

The $375 million FY89 Environmental Protection Agency (EPA) research and development (R&D) budget request is $23.2 million or 7 percent more than enacted FY88 levels.

EPA's FY89 R&D budget represents 8 percent of its total appropriations request. Of the $63 billion Federal R&D budget for FY89, EPA's portion is 0.5 percent. While overall Federal R&D spending will increase 4 percent in FY89, EPA's will increase 7 percent.

Adjusting for inflation, a long term decline in EPA's R&D budget decreases becomes apparent. The $375.2 million FY89 request is equivalent to roughly $184 million in constant 1976 dollars.

By media program, EPA's research and development request for FY89 represents numerous budget and policy changes:

-- Air Research, scheduled at $72.5 million is 6.4 million above FY88 levels. The proposed $8 million increase for stratospheric modification is responsible for this.

-- Water Quality Research would increase $1.4 million or 6 percent to a level of $25.1 million.

-- Drinking Water Research, for which EPA requests $22.0 million in FY89, would remain the same as in FY88.

-- Hazardous Waste Research wvould be funded at $41.3 million in FY89, $3.1 million or 7 percent less than FY88 levels.

-- Pesticides Research funding level is requested at $14.4 million in FY89, 11 percent more than FY88, emphasizing the development of destruction technologies for cancelled and suspended pesticides.

-- Radiation Research would increase $1 million or 35 percent to a level of $4 million in FY89, with an emphasis on radon.

-- Interdisciplinary/Intermedia Program Research would increase $7 million or 26 percent in FY89 to a level of $34.2 million. A new risk assessment

program, to be funded at $10 million in FY89, is responsible for this aggregate increase.

-- Toxic Substances Research, proposed at $26.6 million for FY89, is $0.4 million or 1.5 percent less than FY88 levels.

-- Energy Research requested at $55.5 million in FY89, is 0.5 percent less than FY88 levels. Within this program, the $52 million for acid rain comprises almost 95 percent of the program.

-- Program Management and Support Costs would increase 12.8 percent or $4.4 million to replace wornout lab equipment.

-- Superfund Research, tied to cleaning up abandoned hazardous waste sites, would be funded at $66.7 million in FY89, $7.6 million or 13 percent above FY88. Almost all of the proposed increase is for assessing and developing biosystem destruction technologies for hazardous wastes.

-- Leaking Underground Storage Tanks research is scheduled at a level of $800,000 for FY89, no increase over FY88.

By category of research, there are several significant funding changes between FY88 and FY89:

-- Scientific Assessment, for immediate regulatory activities, would decrease $0.1 million to a FY89 level of $13.5 million.

-- Technical Information and Liaison, the transfer of data from EPA to State and local officials for use in decisionmaking, will increase $0.8 million or 24 percent to a level of $4.2 million. A new information/technology transfer program is responsible for this.

-- Monitoring and Quality Assurance will decline $1.5 million to a level of $42.7 million, with a slight decrease for air and an increase for water.

-- Health Effects, proposed at a level of $45.5 million, would decrease $1.5 million or 3 percent under the proposed FY89 budget.

-- Environmental Engineering and Technology will increase $2.4 million or 6 percent from FY88 levels to $44 million, which can be attributed to developing destruction technologies for pesticides.

-- Environmental Processes and Effects will decrease $0.3 million or 0.3 percent to $42.7 million in FY89.

RESEARCH AND DEVELOPMENT IN THE FY89 EPA BUDGET PROPOSAL

INTRODUCTION

The President requests $375.2 million for EPA's research and development (R&D program, including both in-house and contractual research. [1] Comparing the FY89 request to FY88 enacted levels reveals a $23.2 million or 7 percent increase. Similarly, comparing the FY89 requested levels to actual FY85 levels shows a $72 million or 24 percent increase, owing primarily to increases in Superfund-sponsored research. However, the rest of program has increased only $10.6 million or 4 percent (excluding L.U.S.T.) during the same period. Table 1 depicts these changes since FY85, as well as presenting dollar and percentage changes since FY88.

EPA's $375.2 million R&D budget comprises roughly 8 percent of the total FY89 appropriation request for the Agency. Of the entire Federal $63 billion FY89 planned R&D budget, EPA's portion represents 0.5 percent. And, compared to the overall proposed increase of 4 percent for the Federal R&D budget, EPA's share will increase 6.6 percent in FY89.[2]

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[1] This report deals with the total funding for EPA's Research and Development Program, and includes EPA salaries and expenses, and funding from their research and development appropriations account. That account reflects extramural or outside research, for the most part.

[2] See: Office of Management and Budget. Budget of the United States. FY89. Special Analysis J. p.J-5.

This aggregate increase in the EPA research and development program, 7 percent more than FY88 levels, is in current dollars, not adjusted for inflation. If adjusted for inflation, the differences since 1976 become more pronounced. For instance, using 1976 as a base, since it represents the first year that all major media research programs were active, the current $375.2 million R&D request is equivalent to roughly $184 million in constant 1976 dollars.[3] The real or actual appropriation for R&D in FY76 was $177 million.

The most apparent R&D fund issue for the 100th Congress is: how effective a research and development program can EPA administer with no real fudning increase for most activities. Beyond this overall concern there are several policy issues hinging on major new responsibilities. These include a major research effort on stratospheric modification intended to lay the foundation for decisions, to be made by 1994, on controlling Chloroflourocarbons (CFCs) under the Montreal Agreement. In addition, developing destruction technologies for pesticides and hazardous waste is an expanding area and has significant budget ramifications since the Agency itself has major, increasingly costly responsibilities for destroying cancelled and suspended pesticides, and for cleaning up hazardous waste sites.

Research and development is discussed according to the individual media programs and again by the types or categories of research. Specific research and development programs such as exploratory, acid rain and Superfund research will also be addressed.

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[3] This analysis uses the GNP price deflator for government purchases of goods and services, non-defense sector. The 1988 and 1989 figures used were projections by the Council of Economic Advisors. Fiscal Years were equated with calendar years for purposes of the analysis.

RESEARCH BY MEDIA PROGRAM

The research and development program can be examined through by the individual programs. Table 1 shows the media programs' FY85-89 funding history.

Table 1.
Environmental Protection Agency
Office of Research and Development (ORD)
Budget Authority, FY85 - FY89 Request

Program	FY85	FY86	FY87	FY88 Enacted	FY89 Request	Change $	FY89 %
Air Quality	$67.8	$68.4	$64.5	$66.1	$72.5	$6.4	9.6%
Water Quality	31.4	29.0	24.2	23.7	25.1	1.4	6.0%
Drinking Water	24.9	25.2	23.7	22.0	22.0	0.0	0.0%
Hazardous Waste	40.8	54.2	50.6	44.4	41.3	-3.1	-7.1%
Pesticides	10.4	12.3	12.8	13.0	14.4	1.4	11.1%
Radiation	2.1	0.2	2.7	3.0	4.0	1.0	34.7%
Interdisciplinary	25.9	25.7	25.5	27.1	34.2	7.1	26.3%
Toxic Substances	26.2	36.5	31.7	27.0	26.6	-0.4	-1.5%
Energy	58.3	61.6	59.5	55.8	55.5	-0.3	-0.5%
Program Management	3.7	3.8	3.7	3.9	4.4	0.5	12.8%
Support Costs	5.5	5.9	5.9	6.3	7.8	1.5	23.8%
SUBTOTAL ORD	$297.2	$322.8	$304.5	$292.2	$307.8	$15.6	5.3%
Superfund	12.5	10.5	38.7	59.1	66.7	7.6	12.9%
Leaking Underground Storage Fund	0.0	0.0	0.0	0.8	0.8	0.0	0.3%
TOTAL ORD	$309.7	$333.3	$343.2	$352.1	$375.2	$23.2	6.6%

Prepared by the Congressional Research Service,
Using EPA Data

Air Research

The $72.5 million FY89 research request for the air program is 9.6 percent or $6.4 million greater than FY88 enacted amounts.[4] A major increase of $7.8 million for stratospheric modification research is the contributing factor for this program's expansion. Almost all of the stratospheric modifcation research program is extramural or outside, contractual research. This increase is a budgetary response to major new stratospheric ozone responsibilities, and specifically to the recent Montreal Protocol which sets 1994 deadlines on tightening controls on CFCs. According to EPA, the additional $7.8 million would "provide an expanded research program on the effects of ozone depletion and resulting increases in ultraviolet-B radiation on human health and the environment."[5] Connected to this is an EPA research program on global warming, to be continued in FY89.

While the major new emphasis is the ozone research program, the other parts of the air research program would remain at FY88 levels, or decrease very slightly. Remaining at FY88 levels are scientific assessment activities which directly support regulatory and decisionmaking efforts, and environmental processes and effects research, as well as (Air) characterization, transport and fate research. Funding for the air monitoring and quality assurance activities, health effects and control technology research activities would decline marginally in FY89, according to EPA's budget justifications.[6]

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4 FY89 budget justifications, p. A-8.

5 FY89 budget justifications, p. A-22

6 FY89 budget justifications, p. A-8.

Water Quality Research

The FY89 request seeks $25.1 million for the water quality research program, which is 6 percent or $1.4 million more than FY88 enacted levels. This request represents marginal increases in all six water quality research activities.[7] In commenting on these marginal increases, EPA states for each research activity that the increases reflect "a general enhancement of inhouse support..." which might be interpreted as covering normal salary and operating increases.

Drinking Water Research

The funding for drinking water research would remain roughly at the FY88 level of $22 million in FY89. The allocations for drinking water monitoring and health effects research activities would reamin level in FY89, while the scientific assessment, control technology, and environmental processes research would remain level.[8]

Hazardous Waste Research

The FY89 request of $41.3 million for the hazardous waste research program is $3.1 million or 7 percent less than FY88 enacted levels. The major contributing factor to this planned reduction is the elimination of funding for integrated hazardous waste research, for which $2.8 million was enacted in FY88.[9] These funds support programs at the Center for Environmental Management

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[7] FY89 budget justifications, p. WQ-10.

[8] FY89 budget justifications, p. DW-9.

[9] FY89 budget justifications, p. HW-8,9.

at Tufts University, which EPA feels "...is now fully established and should seek continued funding on a competitive basis."[10]

As for the other components of the hazardous waste research program, scientific assessment, monitoring and quality assurance, health effects, and environmental processes, would remain a roughly FY88 funding. The other component -- control technology -- would decline marginally in dollars and personnel. EPA credits the dollar decrease to "phasing down of engineering evaluations of best demonstrated applicable technology (BDAT) in support of the land disposal restrictions program."[11] In addition, EPA notes that the workyear decrease -- 8.1 workyears -- "reflects an Agency initiative to shift some hazardous waste engineering personnel to the Superfund Innovative Technology Evaluation (SITE) program."[12]

Pesticides Research

The EPA budget seeks $14.4 million for pesticides research in FY89, an increase of $1.4 million or 11 percent above FY88 enacted amounts. All of the increase is for environmental engineering, or control technology.[13] "The increase will fund additional testing and evaluation of environmentally sound and cost-effective technologies for the destruction and disposal of pesticides which have been cancelled or suspended under FIFRA."[14]

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[10] FY89 budget justifications, p. HW-19.

[11] FY89 budget justifications, p. HW-17.

[12] FY89 budget justifications, p. HW-17.

[13] FY89 budget justifications, p. p-8,9.

[14] FY89 budget justifications, p. P-16.

The other components of the pesticides research program would remain at roughly FY88 levels.

Radiation Research

For FY89, the amount requested for radiation research is $4 million, which is 35 percent or $1 million more than FY88 enacted levels. All of this increase is for control technology research "to initiate additional radon mitigation demonstrations and to conduct analyses of the data which will be gathered at the demonstration sites."[15] The other part of the radiation research program, monitoring support for the Department of Energy at the Nevada test site and other test sites, would remain at FY88 levels.

Interdisciplinary/Intermedia Research

The FY89 request for the interdisciplinary/intermedia research program is $34.2 million, 26 percent or $7.1 million more than FY88 levels. The main contributing factor to this increase is $7 million for a risk assessment program, titled Reductions of Uncertainties in Risk Assessment (RURA).[16] All of this research program is extramural or conducted outside the Agency. The RURA program has two foci on human health risk assessment, and ecological risk assessment, and much of the planned increase will be for the latter.

The scientific assessment and monitoring and quality assurance portions of the program would remain at roughly FY88 levels. Increasing under the proposal would be technical information and liaison funding as a response to a new

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[15] FY89 budget justifications, p. R-11.

[16] FY89 budget justifications, p. I-7.

mandate placed on the Agency by the Federal Technology Transfer Act of 1986.[17] This Act expands technology transfer and regional liaison efforts "to enhance scientific and technical knowledge on environmental protection with the public and private sectors."[18]

The exploratory core program would be reduced marginally, and has declined by about 25 percent since FY85. Some funds and program responsibility were transferred to the National Science Foundation in FY86. The three major activities -- grants and centers program, visiting scientists program, and small business innovative research program -- would be funded at the same levels and have roughly the same outputs in FY89 as in FY88.[19] [20]

Toxics Substances Research

The FY89 budget request of $26.6 million is $0.4 million or 1.5 percent less than enacted FY88 funding for the toxics research program. Each of the activities in this program would remain at roughly FY88 levels, while the overall decrease is due to the reduction of funds for the purchase of equipment.[21]

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[17] P.L.99-502.

[18] FY89 budget justifications, p. I-13.

[19] FY89 budget justifications, p. I-15.

[20] The eight university exploratory research centers, to be funded at $560,000 each in FY89, include: Louisiana State University (hazardous waste), Cornell University (ecosystems), Illinois Institute of Technology (industrial wastes elimination), University of California at Los Angeles (intermedia transport), University of Rhode Island (marine sciences), University of Pittsburgh (environmental epidemiology), University of Illinois at Urbana (control technology), and Rice/University of Oklahoma/Oklahoma State University (groundwater).

[21] FY89 budget justifications, p. TS-8,9.

Energy/Acid Rain Research

The FY89 requested level for the energy program is $55.5 million, $0.3 million or 0.5 percent less than current FY88 levels. Of the $55 million requested, $52 million would be allocated to acid rain research.

Multimedia research comprises the entire energy research program. Research funding for acid rain would actually decrease slightly for the first time, while research on control technologies would remain at roughly FY88 levels.[22]

Program Management and Support Costs

As indicated in Table 1, the FY89 request seeks increased funding for both program management activities and support costs. Program management funding would increase 13 percent under the proposal reflecting "a general enhancement of in-house support for program management activities of the Office of Research and Development."[23] The 24 percent increase for support costs is to replace old, wornout scientific equipment at ORD's seven remote labs, and to cover higher operation and maintenance costs at these labs.[24]

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[22] FY89 budget justifications, p. E-5.

[23] FY89 budget justifications, p. MS-16.

[24] These seven labs are located at Narragansett, Rhode Island; Athens, Georgia; Gulf Breeze, Florida; Ada, Oklahoma; Duluth, Minnesota; Las Vegas, Nevada; and Corvallis, Oregon.

Superfund Research

Superfund research and development supports the Agency, States and industry in resolving technical problems which inhibit effective removal of abandoned waste and remedial acts for waste sites.

The $66.7 million request for Superfund research is a 13 percent or $7.6 million increase over current year funding. Superfund research would account for about 18 percent of EPA's total $375.2 million research program. Funds are derived not from general appropriations but from a separate fund largely maintained by industry fees. Since its first year, FY81, Superfund research and development has steadily increased; and there have been major increases since FY85, as indicated by table 1. (Of the total $1.6 billion request for Superfund, R&D funds represents 4 percent.)

Two areas of Superfund-related research would be the beneficiaries of this planned increase: control technology, and environmental processes and effects. The budget seeks $6.3 million in additional funding for assessing and developing waste destruction technology. According to EPA, the increase is for research on the use of biological degradation (biosystems) at Superfund cleanup sites, establishment of a Superfund Innovative Technology Evaluation (SITE) information clearinghouse, increased project management for the SITE technology demonstration program, and costs necessary to provide equipment for the test and evaluation facility in support of the SITE program at Edison, New Jersey.[25] The $1.7 million increase for environmental processes and effects research would also be directed to evaluating biological (biosystems) for waste degradation.

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[25] FY89 budget justifications, p. SF-19.

The other areas of Superfund research -- scientific assessment, monitoring, health effects, exploratory and technical information and liaison -- would remain at FY88 levels.

Leaking Underground Storage Tanks

. In support of EPA efforts to regulate underground storage tanks and prevent leakage for these tanks, EPA conducts a research program for which roughly $800,000 is requested for FY89, the same level as in FY88. All of this program is for engineering evaluations of past and on-going cleanup activities.

RESEARCH BY CATEGORY

EPA conducts six types or categories of R&D. Each has its own purpose or mission, and the funding levels indicate changes in EPA's policy towards those missions.[26] The six basic categories addressed in this section are: (1) scientific assessment, (2) technical information and liaison, (3) monitoring systems and quality assurance, (4) health effects, (5) environmental engineering and technology, and (6) environmental processes and effects. In addition to these there are several other categories already addressed within the previous media program section with very specialized focuses, including Great Lakes, exploratory research, program management and support, acid rain, integrated hazardous waste management, stratospheric modification, and characterization transport and fate, as well as the new risk assessment

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[26] EPA does not, in its formal budget justifications to Congress, present its R&D budget with aggregate totals for research categories. Only within each media research program are these categories discussed. CRS has examined each element of research and compiled this table, which is designed to demonstrate research category trends. However, these figures do not give a full accounting as some minor programs have been omitted.

program. Since these special program were already addressed in the previous section, they will not be discussed here. Table 2 shows research categories, and funding history since FY85.

Scientific Assessment

Representing 3.6 percent of EPA's total FY89 R&D budget is the $13.5 million for scientific assessment activities. This area of research is needed for near-term regulatory development, especially for health and risk assessments. It might be considered the area of research closest to the decision making process.

Funding would decrease slightly for this research component. The $13.5 million scientific assessment request is 0.7 percent or $0.1 million below FY88 estimates, as noted in table 1. Minor decreases in several of the media scientific assessment activities account for the aggregate proposed $100,000 decrease.

Technical Information and Liaison

In the aggregate, technical information and liaison, all of which is under the Interdisciplinary Program, with a proposed level of $4.2 million for FY89 comprises 1.1 percent of the total $375.2 million R&D funding request. This component includes those aspects of EPA's R&D program which attempt to place data and information in the hands of EPA decisionmakers, EPA regional offices, States and localities, and industry. The FY89 level represents a major 24 percent increase above enacted FY88 levels, all of which is due to new technology/information transfer activities in the

Table 2.

EPA Research and Development Program, FY85 - FY89 Request
By Scientific Activity
(budget authority in millions of dollars)

Research Category	FY85 Actual	FY86 Actual	FY87 Actual	FY88 Enacted	FY89 Request	Change FY89 - FY8 $	Change FY89 - FY8 %
Scientific Assessment	$11.2	$13.5	$13.8	$13.6	$13.5	-0.1	-0.7%
Technical Information and Liaison	2.8	2.6	3.1	3.4	4.2	0.8	24.0%
Monitoring Systems and Quality Assurance	37.8	47.1	46.4	44.2	42.7	-1.5	-3.4%
Health Effects	54.5	50.2	48.4	47.0	45.5	-1.5	-3.3%
Environmental Engineering and Technology	60.5	50.3	45.0	41.6	44.0	2.4	5.8%
Specialized Programs							
Environmental Processes and Effects	39.6	46.0	44.1	42.9	42.7	-0.3	-0.6%
Great Lakes Study	2.3	2.5	1.9	1.9	2.0	0.0	0.5%
Exploratory	20.9	21.2	19.2	16.6	16.0	-0.6	-3.4%
Program Management	3.9	3.7	5.0	3.9	4.0	0.1	3.5%
Acid Rain	38.0	47.4	53.8	52.2	52.0	-0.2	-0.5%
Integrated Hazardous Waste Management	0.1	2.4	2.5	2.8	0.0	-2.8	-100.0%
Stratospheric Modification	0.8	7.2	2.1	3.8	11.8	8.0	212.0%
Char Trans. & Fate Oxid. Air	9.1	11.4	10.7	11.1	11.2	0.2	1.4%
Support Costs	5.6	5.9	6.0	6.3	7.8	1.5	23.8%
Risk Assessment (RURA)				3.0	10.0	7.0	233.3%
TOTAL	$287.0	$311.4	$302.2	$294.4	$307.5	$13.0	4.4%
Superfund	12.5	10.5	38.7	58.7	66.8	8.1	13.9%
L.U.S.T.	0.0	0.7	0.7	0.8	0.8	0.0	0.2%
TOTAL	$299.4	$322.7	$341.6	$353.9	$375.1	$21.2	6.0%

NOTE: This table demonstrates the general funding trends in EPA's Research and Development Program and is not intended to give a full accounting, as some minor activities have been omitted. Thus, the figures presented in this table differ from those given in Table 1.

Monitoring Systems and Quality Assurance

For monitoring and assuring the quality of EPA's environmental activities, the FY89 request seeks $42.7 million, some $1.5 million or 3 percent less than FY88 levels. Decreases in air and increases in water quality are part of this planned change. This category accounts for about 11 percent of EPA's total R&D program.

The monitoring systems and quality assurance component develops and transmits to EPA, and State & local officials, techniques for monitoring pollutants and assuring the accuracy and reliability of data.

Health Effects

Comprising 12.1 percent of the total $375.2 million R&D proposal is the $45.5 million request for health effects research. In this category, the research investigates human health effects from exposure to pollutants both as a preliminary to risk assessment and for use in long-term studies. The $45.5 million requested would be $1.5 million or 3 percent less than FY88 levels, due to decreases in water quality and drinking water programs .

Environmental Engineering and Technology

On the technical side of the R&D program, environmental engineering and technology research develops control systems and pollutant removal techniques in support of planned regulatory development.

EPA seeks $44.0 million for its environmental engineering and technology program. This represents a 6 percent or $2.4 million increase over enacted

FY88 levels. There has been a continuing decreased funding for all media programs since FY85. The major contributing policy factor to this trend is EPA's decision to reduce Federal spending in this area in the belief that industry should more appropriately do such research in instances where industry would be the beneficiary. The EPA would be the beneficiary of the two areas of research, pesticide and hazardous waste destruction, empahsized by the FY89 increases

In the FY89 request, a proposed increase in the pesticides program of $1.4 million would fund research for evaluating destruction of pesticide disposal technologies.

Environmental Processes and Effects

Environmental processes and effects is the category of research that focuses on the ecological effects of pollutants. It includes research on the dynamics of the environmental medium in question, and the effects of pollutants on particular media.

For the environmental processes and effects category, EPA requests $42.7 million in FY89, which is slightly -- 0.6 percent -- under enacted FY88 levels.

RESEARCH AND DEVELOPMENT ISSUES FOR CONGRESS

Aggregate Funding Levels

Congress will determine, as part of the HUD-Independent Agencies Appropriations bill, the aggregate funding for EPA's R&D programs. As discussed here, ORD funding is scheduled to increase nearly 7 percent in FY89. Given the proposed budget deficit and already adopted House and Senate Budget

Resolutions, it is doubtful whether there will be funds available to increase EPA's ORD aggregate funding level. Rather, the focus will probably be on whether the most appropriate mix of funds among the various programs and activities, and whether or not Congress may wish to reorder funding priorities as presented by the Administration.

What Components of EPA's R&D Budget Should Be Emphasized?

Once the decision on EPA's aggregate funding level has been made, Congress has the option, through the appropriations process, to emphasize particular aspects of the program within the final appropriation. In this process, the needs of numerous research and development activities must be weighed against one another before final budget decisions are made.

Stratospheric Modification: An R&D Challenge

The 1987 Montreal Protocol represents a serious research challenge to ORD, namely, to embark quickly and efficiently on a research program to provide scientific data upon which a series of decisions must be made -- by 1994 -- on tightening controls and CFCs, which are depleting the stratospheric ozone layer. This research would be entirely extramural. FY89 is a critical year, since many initial questions must be addressed, and the budget's planned increase of $7 million for the program recognizes this. In 1989, two main outputs are planned: completion of a status report on solutions to stratospheric ozone depletion, and the related task of completing an implementation plan for global climatic change.

The enormity of the research task and its direct connection to necessary national and international decisions, make it a research program deserving of

close scrutiny and oversight now and through FY89. Its results will enable Congress and the Administration to begin making some of the many policy decisions that must be addressed by 1994.

Improving Risk Assessments

Another emphasis of the budget is the new risk assessment program -- Reduction of Uncertainties in Risk Assessment or RURA. Its cross media application and focus places it in the interdisciplinary/intermedia research program and all research will be extramural. It has two research directions: part aimed at evaluating human exposure and part directed at evaluating risk to the ecological system.

Evaluating risks to humans and the environment from chemical compounds is the very basis of EPA's regulatory effort. The quality of these risk assessments is crucial to providing sound foundations for defensible decisions and regulations in all program areas.

Destruction Technologies

EPA finds itself in thecostly role as recipient of cancelled and suspended pesticides, for which it must find appropriate methods of disposal and destruction. The budget proposal seeks a 63 percent or $51.4 million increase in pesticides funding for FY89, all of this increase for disposal of 2,4,5 -T/silvex and dinoseb. There are indications that the Agency's responsibility and funding needs for this area could increase significantly in the future.

In light of this, the budget proposes an increase for the pesticide research program of $1.4 million for testing and evaluating

destruction/disposal technologies for cancelled and suspended pesticides. This is a clear example in which the research findings have the potential for reducing the future budget burden from other EPA activities, in this case the enormous financial burden of disposing cancelled and suspended pesticides.

So, too, could Superfund's control/destruction technology activities have a probable direct effect on Superfund cleanup activity costs and, perhaps, significant budgetary savings too. For Superfund research, the budget seeks $6 million more for control technology research. Control technology accounts for one-half the total Superfund research and development proposal. Much of this increase would be for expanding research on biological degradation or biosystems for use in cleaning up Superfund sites, as well as Superfund's Innovating Technical Evaluation (SITE) efforts. These research results could also lead to significant cost savings in the Superfund program.

Both these areas are interesting examples where applied EPA research may provide significant cost savings to the programs involved.

Cooperative Research

Unfortunately, the budget proposal does not identify areas of cooperative research between EPA and universities or industries. Given that there are no funding increases planned for most of EPA's program, these arrangements offer opportunities for addressing research needs with more than just Federal dollars. Congress may wish to more fully identify areas of past cooperation, including the costs and savings involved, as well as areas for potential future cooperation. The 1986 Federal Technology Transfer Act encourages these arrangements.

In-House Research

For several years, there has been concern over the Agency's in-house research and development capabilities. The major funding increases proposed -- stratospheric modification, RURA, Superfund and pesticides -- are being directed to extramural or contractual research efforts. Most of EPA's in-house research program would remain at FY88 levels. Congress may wish to examine more closely the in-house research needs, including personnel and equipment.

United States Environmental Protection Agency
Office of Research and Development Washington, DC 20460

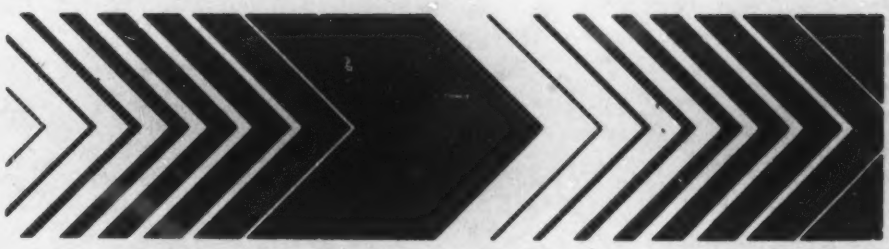
EPA

Research Grants Program

IMPACT REPORT

Environmental Engineering

March 1988



PREFACE

The U.S. Environmental Protection Agency's Office of Research and Development (ORD) established the Research Grants Program within the Office of Exploratory Research (OER) in 1980. The objective of this program is to develop an effective means to stimulate extramural scientists to work on EPA's technical problems, to complement existing EPA programs and to provide a stronger creative base for mission-oriented research needed for the Agency's regulatory and enforcement purposes. To date, through its Research Grants Program, OER has supported approximately 600 research projects in priority areas of enviornmental health, environmental biology, environmental engineering, environmental chemistry/physics (air) and chemistry/physics (water).

In October 1987, OER initiated a reivew and evaluation of the investigator initiated research grants program. This was accomplished by two mechanisms. One was an idependent assessment conducted by the American Management System of the program's role in Federal environmental research, and to identify opportunities for improvement. The report of this assessment is avaiable from OER. The other was the preparation of reports by the Chairmen of peer review panels on the impact of the competitive research grant program in their discipline area. This is one of those reports.

Evaluation of the Projects Supported by the Program in Environmental Engineering

Report Prepared for the

Office of Exploratory Research
U.S. Environmental Protection Agency

by

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A. Introduction

The EPA Extramural Research Grants Program has as one of its major purposes that of creating new engineering and scientific knowledge of environmental control and enhancement in order to serve the needs of society. In addition, there are many other values associated with such research support. These include the development and continuing maintenance of a pool of engineers and scientists with specific disciplines of environmental engineering research expertise, as well as the long term benefits of fundamental research into scientific mechanisms involved in environmental enhancement.

The role of environmental engineering in the Extramural Program is primarily that of basic research and application of research results of scientists and engineers in the areas of potable water, wastewater, air, and solid wastes. The longer term and more fundamental nature of this research is in contrast to the more mission oriented research supported by EPA laboratories. Environmental engineering research and implementation studies have been a major component of federally sponsored research efforts since a half century ago, when initial efforts were made to control the pollution of rivers, lakes and harbors. Increasingly accelerated progress has been made since that time, nearly all of which has been stimulated and largely influenced by the Extramural Research Grants Programs of EPA and its forerunners.

The objectives of this report are to evaluate the publications which have resulted from extramural funding of environmental engineering research, discuss benefits which have accrued in addition to publications, and provide an

overview of other values of such funding support in solving the environmental problems of today and in preparation to address the problems of future generations.

B. Publications Analysis

One indication of quality of environmental engineering research supported by EPA extramural funding is the numbers of technical publications which result from these studies. In environmental engineering there have been at least 200 such articles in peer reviewed publications since the Exploratory Research Program was implemented in 1980.

The published research results have documented significant breakthroughs in the solution of problems in the four areas of potable water, wastewater, air and solid wastes. One of the highlights in potable water research publications has been the discovery that trace organics in drinking water which are derived from man-made materials can be dangerous as potential carcinogenic agents. Such compounds, some of which are known as trihalomethanes, have been identified and are now normally included in drinking water analysis protocols. Research publications on trace organics in drinking water have described not only the development of sophisticated new analytical methods, but also new treatment technology developed by environmental engineers to inhibit the formation of these compounds and to remove those which continue to persist in drinking water supplies.

Publications in waste water treatment have documented the significant strides which have been made in the discovery of new treatment methods and in modifications of existing processes in order to keep pace with the continuing develop-

ment and manufacture of new products for consumer use. A representative area in which research progress has been documented in numerous technical reports is that of anaerobic treatment processes which are highly efficient in decreasing the pollutional nature of wastes as well as in the production of a useful methane gas by-product as an energy resource. The necessary biological reactors are highly sensitive to operational characteristics, and research such as biofilm kinetics to provide increased knowledge of the process in both laboratory and full scale plants, such as that serving the city of Philadelphia, have shown that small additions of selected mineral salts can accelerate the anaerobic biological reactions and prevent plant upsets. This research has resulted in large savings in avoiding plant expansions and in bringing about increased plant reliability.

In air pollution control a major concern over the past decade has been the emissions resulting from the incineration of hazardous wastes. When toxic and hazardous wastes containing chlorinated hydrocarbons are incinerated under certain temperature conditions, they have been known to produce air emissions containing small quantities of the deadly chemical family known as dioxins as air emissions. Research supported by the EPA Extramural Research Grants Program over the past three years has resulted in numerous publications which describe how co-incineration with methane can avoid the formation of these toxic by-products. A highly significant spin-off of this research has been the finding that the chemical reactions inherent in incineration can also be modified to produce valuable feedstocks such as acetylene and ethylene.

Solid waste research supported by EPA extramural funds has been related largely to process modifications which have resulted in the reduction or elimination of

these solid wastes, treatment of solid wastes which have accumulated over time, control of ground water contamination from solid wastes, and restoration of contaminated sites, all of which have been extensively reported in the scientific and technical literature. A typical area in which engineering has been involved has been in the mathematical modeling of groundwater contamination in order to detect the sources of and movement of underground contaminated drinking water strata. These models have increased in number from a handful a decade ago to more than 500 today, and with increased sophistication such that the most complex often require sophisticated computer analyses. These groundwater studies have thus been instrumental in protecting the nation's underground water resources, and in the clean-up of contaminated sites.

C. Highlights Not Necessarily Related to Publications

EPA extramural research support has resulted in significant progress in environmental enhancement through engineering applications of scientific discoveries. One has only to travel by air to our nation's major cities to observe the substantial improvement in air quality which has taken place over the past decade. These air quality improvements are particularly spectacular when observing the brilliance of the skies over cities when lighted at night by both city and automobile lights.

Another major area of beneficial change has been that of the recycling of process waters and materials during manufacturing operations. These engineering and resource conservation changes have been made possible by the development of new technologies based upon EPA extramural funded projects over an array of disciplines, and often taking advantage of interdisciplinary studies carried out at universities. The results have been the development of pro-

cesses which allow certain industries to operate within a closed system, thus achieving environmental control and resource conservation, as well as zero discharge of both wastewater and contaminated materials.

Beneficial changes in use patterns by the consuming public have also been achieved through environmental engineering research supported substantially by EPA extramural funding. For example, lead-free gasoline is now not only accepted but even a preferred product, through efforts of chemical engineering and other disciplines which developed substitute octane enhancing materials. Likewise, biodegradable detergents are now standard products, resulting largely from research by chemists and chemical engineers at M.I.T. and elsewhere and supported by extramural funding from agencies which were forerunners to EPA. The list of substitute products for American consumers which have resulted from environmental engineering research input is long and varies from products to replace asbestos insulation to those that replace the PCB's previously found in uses ranging from transformer coolants to fluorescent lights.

One of the major accomplishments of the extramural research grants program is the development at a number of universities of world renowned programs in selected areas of environmental engineering research and development. A case in point is the area of solids/liquid separation, particularly in deep bed and precoat filtration. Early studies were funded by a series of U.S. Public Health Service (forerunners of EPA) grants in the area of diatomite and deep-bed filtration. The results led to publication of chapters in texts and reference books such as PHYSICOCHEMICAL PROCESSES FOR WATER QUALITY CONTROL; WATER SUPPLY ENGINEERING; WATER TREATMENT PLANT DESIGN; FILTRATION AS A

LABORATORY TOOL IN SEPARATION AND PURIFICATION; THE SCIENTIFIC BASIS OF FILTRATION; MATHEMATICAL MODELS AND DESIGN METHODS IN SOLID-LIQUID SEPARATION.

The EPA subsequently supported continuing research under the extramural grants program in the development of backwash requirements for filters used in wastewater filtration applications. Later, EPA sponsored university faculty support in disseminating the design recommendations in ten to fifteen seminars around the country. The research results here led to creation of an International Consortium of Filtration Research Groups, (INCOFILT), which regularly brings together researchers from the U.S.A., Japan, Israel, West Germany, France, Belgium, the Netherlands, and England.

In summary, research supported by EPA resulted in development and implementation of filtration design criteria for direct filtration plants. As a typical example of application, this technology enabled the city of Los Angeles to build a new public water treatment plant with deep-bed , coarse-media filters that operate at 13 gpm/ft^2. The plant was built at a cost of about $90 million, a savings of more than $200 million over the cost of a conventional plant that was required at the time that filtration research was first supported by the EPA Extramural Grants Program.

D. Other Values Such As Return On Invested Grant Dollars

Over the past three decades, fundamental research in environmental engineering has led to a better understanding of unit operations and processes used in treatment of water supplies and wastewaters, air emissions, and solid wastes. As a result, existing processes have been modified so as to be more cost effective and reliable. Likewise, it has been possible to develop entirely new

treatment processes because of a better understanding of the fundamentals associated with related existing processes.

The benefits and accomplishments resulting from EPA's support of university-based environmental engineering research address two interconnected areas. The first is the need for research to answer many environmental protection questions. These include (1) fundamental questions for which we at the present time have no answers, (2) questions about how to best apply scientific and engineering fundamentals to environmental protection and management, and (3) questions regarding application, design, and implementation of strategies for better, safer or more economical environmental protection or management.

The second area which EPA's support of extramural research addresses is the critical shortage of qualified environmental engineers and technologists. While this shortage has been identified for some years, it continues to grow more acute. For example, current and anticipated regulations clearly will require competent people to design, conduct and monitor cleanup activities. In many cases, these individuals need post baccalaureate education and specific research experience in environmental engineering topics.

EPA's role in environmental engineering education fits firmly within its mission in environmental regulation. The scientific answers and personnel needed for development, implementation, and monitoring regulations are provided largely through university-based research activities. Universities, with their unique climate, offer at least three distinctive features in the conduct of environmental engineering research.

First, nearly all research is carried out jointly with graduate and undergraduate students. Hence, the training of a new generation of environmental engineering professionals occurs along with the discovery of needed answers to technological questions. Furthermore, research activities of university faculty are common topics of discussion in their undergraduate and graduate courses. Consequently, the circle of students influence is larger than just those who work directly on the environmental engineering research project.
Second, the academic setting is particularly well-suited to interdisciplinary work and collaboration with other engineers and scientists either at the same institution or at another location. The pressures of corporate profit or proprietary protection do not exist and researchers are more free to choose the appropriate team of colleagues for each environmental engineering investigation.

Third, research activities at universities are generally less costly than those carried out by government or corporate research firms. This lower cost arises primarily because graduate student researchers are paid only modest stipends, and through the overall support base of the academic institution.

The nature of interdisciplinary research carried out at universities offers the engineering profession an added benefit in working together with science disciplines, with each contributing its technical input individually and collectively in analyzing and solving environmental engineering problems. If the past is any indication, new and yet unidentified future environmental engineering problems and issues will continue to emerge, many of which will require new knowledge and solutions which can be generated most successfully through research carried out by environmental engineers working in an inter-

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disciplinary relationship with the sciences such as biology, chemistry, and physics at universities.

As an example of another similar program, the Department of Defense has established a program, The University Research Initiative (URI), that in 1986 distributed $124 million in contracts specifically for university research. This program recognizes the importance of working with academic institutions in providing equipment and training of students and faculty in research areas of long term military importance (The Scientist, 1987). The potential, mutual benefits of EPA sponsored research within the university community would appear to parallel those of the URI program.

In evaluating the benefits of extramural programs in environmental engineering research, it is important to recognize the difference between that short term research work carried out in government laboratories to support regulatory programs and research at universities which have great impact on technology and costs over the long term. As an example in the field of wastewater treatment (Parker 1987), research at the University of California in the late 1960's was funded by forerunners to EPA in activated sludge process performance. One study concerned the enhancing of flocculation of activated sludge solids prior to secondary sedimentation. Observed turbulence and high shearing rates in the activated sludge basins were found to be inhibiting to good floc formation. A separate mildly stirred flocculation basin was proposed, and bench-scale studies showed that flocculation could indeed be used to advantage in improving secondary effluent quality. This research provided details on optimum flocculator mixing levels and detention times.

The first opportunity to apply the new flocculation concepts at full scale occurred in the mid 1970's at the City of Corvallis, Oregon. The mission was to find a way to avoid using costly effluent filtration to meet new summer discharge standards. It was believed that adding a flocculation step would improve performance and assure that standards would consistently be met. New secondary clarifiers that incorporated flocculator center wells were added. From start-up in 1978, the process met all expectations, and this improvement has now been duplicated in a number of other plants. The process has also recently been set forth in a design manual prepared by the Water Pollution Control Federation in 1985.

An important lesson of this case study is that a $70,000 expenditure for environmental engineering research in the late 1960's has saved millions of dollars in construction and operating costs. In one 50-mgd plant recently constructed, effluent filters would have cost $5.8 million. The cost of adding flocculators to the secondary clarifiers was only $240,000, a savings of $5.6 million. If the value of the initial federal government's research expenditure is stated in today's dollars as $205,000, the original research would have a benefit-to-cost ratio on one project alone of 27 to 1. Considering that the concept has been used in at least seven other locations, the real benefits have been far greater.

EPA forecasts that there will be 2,800 additional plants constructed using effluent filtration by the year 2000, treating a flow of approximately 2,900 mgd (Environmental Protection Agency, 1985). To make a plausible extrapolation of benefits, let's assume a typical cost of about $0.4 million per mgd (Environmental Protection Agency, 1980), and further assume that 33 percent of the

plants could avoid effluent filtration by using flocculator clarifiers. The potential national cost savings are on the order of $380 million, and the potential benefit-to-cost ratio for the research would be a staggering 1400 to 1.

In the case described, a relatively modest initial investment in engineering research led , over the following two decades, to a major payoff in cost savings and technological advances. The advances progressed from basic research studies at the university to an initial application and refinement, and then to broad application in practice. A basic element was federal government sponsorship of the early research by university researchers, and ultimately, very high benefit-to-cost ratios resulted from the research. It is important to remember and consider these case studies in evaluating future EPA Extramural Research Grant Programs in environmental engineering.

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United States Environmental Protection Agency
Office of Research and Development Washington, DC 20460

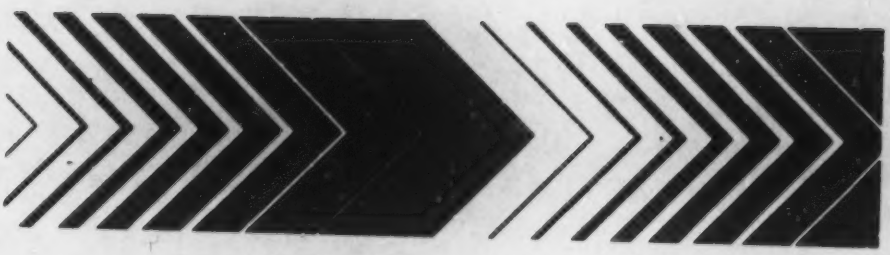
EPA

Research Grants Program

IMPACT REPORT

Environmental Chemistry/ Physics Water

March 1988



PREFACE

The U.S. Environmental Protection Agency's Office of Research and Development (ORD) established the Research Grants Program within the Office of Exploratory Research (OER) in 1980. The objective of this program is to develop an effective means to stimulate extramural scientists to work on EPA's technical problems, to complement existing EPA programs and to provide a stronger creative base for mission-oriented research needed for the Agency's regulatory and enforcement purposes. To date, through its Research Grants Program, OER has supported approximately 600 research projects in priority areas of enviornmental health, environmental biology, environmental engineering, environmental chemistry/physics (air) and chemistry/physics (water).

In October 1987, OER initiated a reivew and evaluation of the investigator initiated research grants program. This was accomplished by two mechanisms. One was an idependent assessment conducted by the American Management System of the program's role in Federal environmental research, and to identify opportunities for improvement. The report of this assessment is avaiable from OER. The other was the preparation of reports by the Chairmen of peer review panels on the impact of the competitive research grant program in their discipline area. This is one of those reports.

Evaluation of the Projects Supported by the Program in Water Chemistry/Physics

Report Prepared for the

Office of Exploratory Research
U.S. Environmental Protection Agency

by

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ENVIRONMENTAL CHEMISTRY AND PHYSICS/WATER (ECP/W)

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1. OVERVIEW AND SUMMARY

The two major research areas of the Environmental Chemistry and Physics/Water (ECP/W) panel are:

1) Analysis: new characterization techniques and methodologies and,

2) Understanding and modelling the transformation, transport and fate of pollutants.

Both study areas are interdependent and involve complex systems. Often important transformation and fate studies cannot be carried out due to the lack of a proper analytical technique; at the same time, advances in analysis or model concepts stimulate new research in other areas. The complexities of ECP/W research require a cadre of scientists expert in many disciplines. The researcher must be knowledgeable in the basic sciences as

well as environmental science and engineering.

Computer simulation models structure the transformation-fate-transport mechanisms in an objective fashion. A model is only as "real" as is the process research that is coded into the model. The calibrated and verified working model is then used by the regulator to pose and answer "What if...?" questions in a rigorous way when developing policy or strategy. Also, these models may be more important as sensitivity indicators of what "we don't know", rather than "what we do know".

A close inter-action of many related disciplines, a most important feature of the ECP/W panel, is required and needs to be continuously exploited in order to solve environmental problems. ECP/W research topics consider the connected disciplines of microbiology, physics, geochemistry, analytical chemistry, biochemistry, electronic, ecology, soil science, civil engineering, physical chemistry, organic chemistry, geophysics, systems analysis, hydrology, and waste treatment technology. Panel membership reflects these areas.

Some of the significant research findings of grantees for 1980-81 are summarized in the following pages. Many of these findings have elucidated solutions in basic science and engineering, as well as to environmental problems. Others have used these and other findings in technology transfer to EPA. Some important advantages resulting from ECP/W research are:

1-- The development of analytical systems to analyze complicated multi-component pollutants at trace levels, involving organics, metal-organics and viruses,

2-- Procedures to measure and sample groundwater dispersion of multiple chemicals at disposal sites, .

3-- Procedures for computing physical/chemical properties of potentially toxic organic compounds, important for fate studies,

4-- Interaction of humic matter and toxic organic substances,

5-- Interactions of organic substances and sediment,

6-- Elucidation of transport and fate in the unsaturated groundwater zone,

7-- Strongly linked laboratory experiments to real world systems,

8-- The assessment of the bio-transformation of toxics in groundwater,

9-- Incorporation of chemical, physical and engineering findings into EPA manuals,

An important highlight of all of this research is the strong multi-disciplinary efforts. Recognizing the need to collate the "state-of-the-art" in various multi-disciplinary thematic topics, the ECP/W has been pro-active in developing timely workshops, involving the best researchers inside and outside of EPA. Workshops have considered "Surface Adsorption", "Metal Speciation", "Organic Acids and Acidification" (February, 1988), "Fate and Transport in the Unsaturated Zone" (May, 1988) and "Contaminant Uptake and Transport in Fine-Grained Sediments" (Fall, 1988). A workshop on "Modelling of Innovative Tertiary Treatment" is also being planned for the Fall of 1988. All workshops produce a publication.

'Crystal ball gazing' suggests research pay-offs will involve in-situ sophisticated multi-sensor instrumentation and work-a-day computer models (emphasizing expert systems) which accurately describe real-world environmental situations; these same approaches will be used in waste technology. To achieve these goals, the environmental community and EPA must be able to tap the best basic and applied researchers in a multitude

of disciplines beyond the obvious reach of EPA. This approach is not readily amenable to the structure of EPA, but is the type of challenge that can be met by the more flexible academic community. A further requirement will be the continuous encouragement of the best young scientists to enter the environmental studies area. And, finally, a strong and real coordination between the Extramural Research Program (ERP), Office of Research and Development (ORD) and EPA program offices will be required for a true technology transfer of the research.

"Science has come a long way and will go a longer way since the invention of the first transistor on December 24, 1924. It is essential to continue visionary and innovative research and development; the alternative is to spend large amounts of funds on intermediate research and technology."

2. ENVIRONMENTAL ANALYTICAL TECHNIQUES AND METHODOLOGY

2.1 Introduction

Environmental sciences rely very heavily on measurement-based disciplines, whether one is interested in monitoring, verification of modeling predictions, or in environmental cleanup. It is essential for intelligent management of the global environment to be able to accurately identify, characterize and quantitate a vast range of species which impact on the inhabitants of earth. This can be achieved only when the requisite analytical tools are in place and available to workers in the various subdisciplines of environmental science.

2.2 Scope

The two major areas of analytical measurements research and development

are: First, of adapting current analytical techniques to pressing environmental problems and providing the tools for a wide spectrum of studies. The second area focuses on the creation/invention of new and innovative measurement schemes to improve our ability to monitor, improve, and maintain the environment. The incredible complexity of environmentally significant situations challenges researchers to develop multifaceted measurement techniques which are both innovative, yet practical and straightforward in use. Descriptions of the accomplishments of some EPA-funded proposals which directly address these two areas are in Section 2.7.

2.3 Measurement Approaches

Static measurements techniques can be used in applications where the environmentally significant quantity of interest fluctuates at a low frequency, e.g., quantitation of batch samples, or monitoring of stable waste sites. Information theory states that measurement need only be taken at a rate of two times the fastest fluctuation of the quantity of interest. Thus, static measurement can provide sufficient information with a minimum of experiments.

Dynamic measurement techniques are essential in some areas of basic and applied research to provide the information to understand the kinetics and mechanistic pathways of chemical interactions and to track changing environmental events. Thus, time-dependent properties may require different measurement approaches to obtain the desired information. It is apparent that the field of analytical techniques and methodology research spans a broad range of approaches to analytical measurements of environmental samples. It is also obvious that analytical techniques and

methodology often provide the keystone for development of a theoretical understanding of processes, implementation of monitoring and clean-up schemes, and for intelligent decision making.

2.4 Environmental Target Systems

The impressive breadth of environmental systems can roughly be grouped into three types, homogeneous, heterogeneous and interface systems. A flow diagram could be envisioned which would delineate sub-categories of specific research interest of different facets of the environmental community in each system. Virtually all of these categories require some form of measurements to correlate facts with theory, and analytical methodology and innovative techniques are major avenues in this endeavor. Indeed, if a flow diagram was constructed of the scope of environmental research targets, with a listing for each of the required and desired measurements to help achieve their goals, the crucial importance of superior analytical techniques and methodology would be impressive. The sheer variety of environmental questions posed demand a large assortment of measurement tools.

2.5 Instrument Development: Laboratory vs Field Units

Laboratory-based instruments are used for (1) measurements in basic research and (2) for measurements of batch samples collected at specific sites by instruments too complex and/or fragile to be transported. However, there are many environmental situations where it would be highly desirable to carry out the measurements directly at the site, either for individually collected samples or for real-time monitoring. The logical

outgrowth of basic research in analytical methodology is development of field units which are practical, reliable, preferably light weight, easy to use, and with a low power demand. This last step, the transfer of innovative technology conceived by basic research to practical applications, is an important aspect of this research program and one of potentially enormous value to the Environmental Protection Agency. Development of innovative laboratory research instrumentation and methods, plus extension of the scientific principles to field units provides a two-fold payback for the grant funds.

2.6 Challenges: Present and Future

We are poised at an exciting and challenging point in measurement science due, in no small part, to **tremendous advances in both hardware and software technology**, e.g., readily available power computer systems and the emergence of "EXPERT" systems which place some decision making and optimization tasks under computer design. Incorporation of these state-of-the-art technologies into environmental problem solving would greatly enhance our abilities to address the pertinent problems and to solve them correctly. Science has come a long way since the invention of the first transistor on December 24, 1924, and it is essential to continue visionary research and development for the safety of our environment using the most modern ideas at hand.

The **explosion** in hardware and electronics development in recent years puts environmental measurements on the edge of a new era of analytical science. One of the many influences that these developments will have in the future is the proliferation of **miniaturized instruments** which

heretofore have been limited to in-house use. Thus, complex measurement systems, such as **Fourier transform IR will become amenable to on-site use** -- or, with proper funding, have the distinct possibility to do so.

Although one tends to associate analysis with physical systems, it is important to point out that there will be an enormous development in **biological sensors** with the continuing development in modern microbiology. Once again, individuals versed in the basic science in this area will be needed to develop these sensors.

An emerging approach in measurement science is **multiple detection schemes applied simultaneously to a single experiment.** This approach maximizes the data obtained per unit time and gives scientists a high duty cycle type of measurement. The advent of hyphenated techniques, such as GC-MS, MS-MS, etc., and the extension of the use of Fourier transform techniques also have great promise in solving environmental problems.

2.7 Multi-Dimensional Concepts

Specific measurement approaches may be roughly divided into optical (EMR), electrical and separations. Samples are perturbed by an external energy source and the samples response in the input is measured. Although some measurement schemes/methodologies are limited to one of the three areas, many schemes are a blend of these approaches, e.g, liquid chromatography with fluorescence detection.

Multi-component priority pollutant samples were analyzed by adsorptive displacement from activated carbon using gas chromatography - flame ionization [Grant #811314]. This study successfully determined 25 base neutral priority pollutants at loadings of less than 0.1 mg/g. The results

showed that most compounds could be quantitated with complete desorption, and incompletely desorbed species concentrations could be accurately determined by calculation. This demonstrates the power of this approach to the determination of complex environmentally-significant species.

Volatile priority pollutants are of special concern and challenge in many laboratories. Isolation and detection of these volatile water pollutants were carried out using direct headspace and aqueous injection techniques. Specifically, halogenated hydrocarbons and chlorinated pesticides were determined by gas chromatography with innovative instrumental variations [Grant #811473]. For example, open tubular columns and a new phenyl-cyanopropyl polymethylsiloxane stationary phase was employed which provided superb separation of 18 volatile priority pollutants. In addition, the kinetics of the abiotic homogeneous aqueous phase elimination reaction of 1,1,2,2-tetrachloroethane to 1,1,2-trichloroethane was determined at a variety of temperatures and acidity levels. These studies shed light on the problem of contamination of drinking water by halogenated organic compounds and the possible changes occurring in these compounds by chemical reaction during water treatment. The results provide valuable insight into these changes and contribute to our fundamental understanding of the chemistry which may be occurring in water treatment facilities. In contrast to the study described above, the species were detected primarily by electrochemical (ECD) means, operating in a different mode.

Another approach to separating compounds in complex samples is by the use of solid/liquid phases rather than by gas/solid phases. Several polycyclic aromatic hydrocarbons were determined by thin-layer chromatography. A variation of this approach, namely high performance TLC, was employed which

gave excellent results [Grant #808854]. By coupling the TLC separation with fluorescence detection, a 100-200 fold improvement in intensity was obtained by application of various compounds to the TLC plates, e.g., triethanolamine. Quantitative results were obtained, with high accuracy and speed, by employing fluorescence scanning densitometry. The simplicity of this approach recommends it to be included in the arsenal of environmental analytical methodology. This project also produced some valuable review and overview articles for use by both established workers, as well as new comers to the field. A related study involved the investigation of secondary cooling gases in cold on-column injection in capillary gas chromatography. Air and carbon dioxide were compared, and the results provided guidelines for optimum experimental design.

The measurement of viral concentration is presently the most significant deficiency in the assessment of water-borne disease. Without reliable detection methods, management and control of this important environmental problem is severely limited. Farrah and colleagues [Grant #810126] of the University of Florida are developing and testing a variety of relatively fast, reliable and economic methods for detecting viruses. This research is developmental and exploratory and has significantly advanced the analytical capabilities in this important area. Their approach is based on concentrating the virus on filters. In particular, these investigators have systematically addressed and circumvented many of the operational problems that are involved in the filtration-concentration process.

Major contributions that have resulted from this research include the systematic evaluation of filter types to assess effectiveness, the development of chemical methods to increase filter efficiency and the

specification of standard methodology and equipment for viral measurement. The results has been a demonstrable increase in the capability to detect viruses in natural waters.

Research aimed at gaining a better understanding of the role trace metals play in the ecology of aquatic organisms focussed on evaluating a novel electrochemical analysis technique. Differential pulse anodic stripping voltammetry was the technique employed for the determination of cadmium(II) metal in aqueous systems with the variation of using a rotating membrane-covered mercury film electrode [Grant #810540]. The effects of acidity, rotation rate, deposition time, and concentration on the accuracy of the determination of cadmium concentration were successfully evaluated, and the sensitivity to low concentrations compared favorably with presently used methods. Another important study examined the effects of the presence of the surfactants in solution which were chosen to model ionic, nonionic, complexing and polysaccharide compounds. The electrode system employed eliminated many of the adsorption problems previously reported with other electrode systems. A major advantage with electrochemical methods is in obtaining accurate results in chemical speciation of water samples. For example, the adsorption of humic substances can drastically alter the results and provide misleading conclusions. This work extends our understanding of the influence of interferences in electrochemical measurements of trace metals.

A different approach to the determination of metal-humic compounds is to measure the change in fluorescence when metals are added to solutions with humics [Grant #812102]. Copper has been used in this study, and the results will give metal speciation constants which can be used to determine

metal-humic binding and suppression of metal toxicity in small ponds and lakes, which are common to many parts of the U.S.

Another study involved the challenge of associating biological effects to forms of methylated tin in the environment [Grant #809416]. This research required the collaboration of a first-rate analytical chemist and microbiologist and the challenge of understanding the effects under real environmental conditions. Thus a protocol evolved for the study of metal speciation and biological effect as well as the results for methyl-tin species.

A different electrochemical detection approach to the determination of molecular species is the microarray of electrochemical flow detectors coupled to a prior liquid chromatography separation scheme [Grant #808084]. The electrodes behaved very well in flow-stream operation, with sub-nanogram detection limits for river water spiked with carbamate pesticides. Studies of mass transport versus electron transfer rate processes were carried out, as well as numerical simulation studies. The results were consistent with theoretical predictions. This work provides an enormous body of fundamental experimental and predictive information on the applicability of membrane modified electrode systems for quantitative analysis of environmentally significant species, and contributes a firm background on which future work can be built. It illustrates a fine blend of experimental and theoretical approaches, as well as basic and applied aspects. It represents a major contribution to the area of electrochemical measurements of hazardous species in water systems.

An excellent example of a multi-pronged approach to measurements of species in the environment is the accomplishments of Grant #810717.

Numerous publications were produced in the open scientific literature detailing various approaches to the determination of primarily molecular species. The techniques developed and/or employed encompass liquid chromatography, chemiluminescence detection, fluorescence detections, phosphorescence spectral evaluation, infrared spectra studies, the use of post-column photochemistry in HPLC, photochemical amplification in HPLC, and whole column detection chromatography. These studies represent advances in simulations of novel measurement techniques, innovative development of analytical techniques, practical applications, as well as very fundamental photophysics of molecular reactions. These results are currently state-of-the-art and will continue to be a major influence on modern measurement research and, therefore, represent a major contribution to environmental analytical techniques and methodology advancements.

Time is a dimension that can be assessed only by examining the stratigraphic record in a core. But this procedure, although often used in a simplistic fashion, is fraught with problems due to changes in diagenetic processes such as diffusion, bio-turbation, differential compaction as well as differences in sedimentation rates. Christensen [Grant #810419] developed a sophisticated deconvolution procedure that allows the determination of pollutant deposition rates in context to other interfering processes. This mathematical calculation is now being subjected to a critical field study for confirmation.

2. TRANSFORMATION AND FATE STUDIES

The drive to develop a capability to predict the degree of dispersion

and concentrations of toxic substances in natural water systems is obvious if we are to calculate, or measure, exposure or dose to the fauna, flora and humans. The two main approaches that have been used are microcosm studies and the integration of information on physical chemical properties of the substance in question with information on the food chain dynamics and hydrodynamic transport models. The two approaches obviously are complementary, although the latter approach is somewhat more general and can serve as a method to organize the tremendous amount of data which often is generated, as a method to examine what properties of the substance determine dispersion, or what physical, biological or chemical processes determine the environmental fate. The kind of information which typically is necessary includes: aqueous solubility, vapor pressure, photolysis rates, abiotic degradation rates (i.e. reactions with ozone, singlet oxygen, or hydroxyl radicals), hydrolysis rates, adsorption/desorption kinetics, Henry's Law constant, microbial degradation rates, octanol-water partition coefficients, and enzymatic reaction kinetics for both invertebrates and vertebrates. These data are then incorporated in transport models for groundwater as well as surface water systems. Models of this type include: EXAMS (EPA, Athens), TOXIWASP, and SOILTEST.

In approaching this kind of modeling, there are three conceptual levels of information that must be considered. First, basic data on rates for homogeneous systems must be available. These data include information on solubility in distilled water (as opposed to mixed solutes and solvents), photolysis rates for the non-adsorbed (atmospheric or aqueous) compound, reaction pathways and rates for homogeneous systems with reactive species ($OH^{\cdot}$, O_3, O) etc. This type of information should be available as a

function of temperature. The second level of information in this modeling approach most include the effects of heterogeneous reactions and phases. Therefore, laboratory data must be developed that examine cosolute and cosolvent effects on solubility and Henry's Law Constant, catalytic or retardation effects on hydrolysis and abiotic degradation rates, effects of adsorption on microbial degradation rates, etc. Thus the approach here is to produce partitioning and rate data which can be measured, or predicted, in a rigorous manner for complicated - yet well defined - systems. The third level of information necessary for this approach includes data from field and microcosm studies. This type of data will incorporate such factors as our (in)ability to clearly separate phases (i.e. "truly" dissolved vs. colloidal or particulate fractions); our (in)ability to measure or identify the chemical species in the vapor or solution phase, or that which is associated with the solid phase; the logistics of sampling (i.e. not enough spatial and temporal resolution), analytical difficulties (QA/QC), and the logistical problems involved in acquiring supporting data as the chemical and physical characterization of surfaces, type of biota, including microbes etc. Information necessary for transport calculations also are required. These include parameters to calculate flow due to advection, turbulence and molecular diffusion.

Parallel efforts should be pursued for all three levels. Much data is still needed for the homogeneous system. Accurate data bases on such basic physico-chemical parameters as solubilities, vapor pressures, absorption spectra (UV, visible, and IR), and boiling point are still missing for thousands of chemicals (including PCDDs, PCDFs, PAHs, azoxy compounds). Activities in pharmacology, chemical engineering, as well as environmental

fate research, need these data bases. An ability to predict these, using a variety of thermodynamic, empirical, and semi-empirical techniques is also necessary since it will be logistically difficult and very expensive to generate laboratory measurements for these properties. The work by Scree **[Grant #812657]** and similar work by other investigators address this topic. Since appropriate data are often unavailable, many modelers now use property prediction techniques interfaced with fate models.

An area requiring increased attention is abiotic and biotic degradation kinetics. Knowledge about their pathways is essential both for prediction of transformation rates but also for waste treatment purposes **[see Grants #808034, 808176, 809561, 811526, 812377, 812913, 812944]**. Air pollution studies have generated a tremendous amount of information on organic chemical reactions with $OH^{\cdot}$, $ROH_2^{\cdot}$, O, and O_3, both for homogeneous and heterogeneous systems. Parallel efforts should be encouraged for aqueous systems. Knowledge of transformation rates, intermediate species, and end products will permit development of models that are capable of predicting response times of chemicals that presently are being released or in situ pollutants. Information gained from these types of studies can also be transferred to the development of control strategies for treating hazardous chemical emissions or dump sites.

Projects by Bollag **[Grants #81158, 808165]**, Carpenter **[811249]**, Pankow **[808272]** and Wofsy **[807081, 810219]**, provide information for the third level. Work from these projects gives us -- (a) Data which are generated in situ. It is important that good data bases are available for comparison with those obtained from either laboratory measurements or modeling efforts. (b) The effect of major and nutrient element cy[illegible]ng on

xenobiotics. Just like major crustal elements dictate behavior of many trace metals, it also seems to be the case with organic carbon (for example, humic and fulvic acids) and nutrients (as they influence productivity) with respect to organic pollutants. (c) General models that may be used to predict transport and fate for a variety of subsurface conditions **[i.e. Pankow, Grant #808272].**

Some summaries of projects are:

811249 Roy Carpenter - Trace Organic Phase Association In Pacific Northwest Sediments

Summary: Factors affecting organic matter cycling in natural waters are part of the fate and transformation category. This type of research, which examines phase partitioning and the physico-chemical state of pollutants in natural waters, provides information which is essential for fate prediction. Carpenter's group studied both the remineralization and diagenesis of organic carbon as well as the behavior of xenbiotics such as PAHs and other hydrocarbons.

Comment: This work is important for several reasons:

a) Data which are generated from in situ studies, and compared with lab data - it is very important that such data bases exist since lab measurements and theories have to be tested in the real world;

b) just like major elements dictate behavior of many trace elements, it is logical that remineralization of organic matter influences the behavior of xenobiotics;

c) these measurements probably give information on "dose" to organisms - or the closest thing, at least that we can measure, which resembles

"dose" in aquatic systems.

Grants #808165, 811518 Jean-Marc Bollag - Investigation of Polymerization of Xenobiotic Aromatic Compounds (e.g. some pesticides) and their Incorporation into Soil and Sediment Humus; Binding of Xenobiotics to Humic Materials and their Release Through Microbial Activity

Summary: Work is described with respect to peroxidase activity in soil. Peroxidase activity is of interest because of its postulated role in decomposition of soil organic matter, in the humification of organic matter, and in transformation of xenobiotics. The author has demonstrated that all these processes are important and that plant roots, bacteria, and fungi all produce peroxidases of interest. Much of the effort produced by this research group is directed towards:

a) extraction, purification and identification of these complex organics;

b) the mechanistic aspects of their interactions with soil organic matter; and

c) xenobiotic interactions with humus as influenced (catalyzed) by these oxidases.

Comment: This type of research falls under fate and transformation but is of particular interest since the peroxydases react with both natural and xenobiotic compounds. Again, one of the most obvious useful results of this research is that it will be possible to predict what kind of xenobiotics will be influenced, and to estimate the rate of reaction of these substances in soil.

809601 Paul V. Roberts - Influence of Physical Structure on Adsorption of Organics by Activated Carbon

Summary: This study determines the diffusion coefficients of humic acid in aqueous solutions similar to groundwater conditions. The transport and fate of humic substances is important because they can form trihalomethanes as well as form metal complexes and yield undesirable color. Thus the minimization of humic acids is important to the quality of potable water. Mixtures of different humate fractions, as well as temperature, were examined in the diffusion studies. In addition, the role of ozone on the adsorbability of organic matter was determined. It was shown that a moderate ozone dose enhanced adsorbability. Analysis of rate of humic acid uptake supports a two-domain diffusion model.

This study is fundamental to the transport and fate of humics and associated organics in groundwater.

808176, 811526 D.K. Button - Degradation Kinetics of Nonpolar Organic Substrates by Microorganisms; Basic Bioconversion Kinetics of Anthropogenic Hydrocarbons and Xenobiotic Amphiphiles in Aquatic Systems

Summary: Many studies involve the study of nonpolar organic compounds and other studies involve the study of polar compounds with function groups. Few studies tackle the most important and complex issue of the rate of degradation of organic compounds. In addition, there is a large group of important substances that have structures partly polar and partly non-polar (amphiphile). These compounds are poorly understood in general and

their kinetics of degradation are very complicated, being affected by many environmental factors. This research is pioneering in that it was one of the first pieces of work to analyze and study the degradation of these substances in an environmental setting.

809561 James O. Leckie - Spectroscopic, Kinetic and Thermochemical Study of Transition Metal Adsorption at the Oxide/Aqueous Interface

Summary: Using a previously developed triple-layer model, the researcher studied the sorption of lead on the iron oxide, goethite. This was pioneering work in the use of pressure jump relaxation technique coupled with EXAFS to define more precisely where the metal was cited. This type of research is fundamental to our better understanding of the nature of bonding in surface reactions, and this information leads in turn to the better definition of the fate of the sorbed pollutant.

812944 Alan T. Stone - Catalysis of Organic Pollutants by Metal Oxide Surfaces

Summary: The enhancement of hydrolysis of a phthalate ester by aluminum oxide suspensions was studied. This mechanistic study showed that the ester first adsorbed to the Al with subsequent attack of OH-ions in the diffuse layer. It is hypothesized that this mechanism should be important for other organic substances and that the kinetics need to be worked out in detail.

Comments: This type of work logically falls under fate and transport of substances in the environment. Most present data models integrate data on physico-chemical properties with hydrodynamic and aerodynamic models.

Such models are immensely valuable in that they may be used to test what processes or properties of a compound are mostly responsible for observed behavior. The properties of interest are: aqueous solubility; saturation vapor pressure; Henry's Law Constant; Octanol-water partition coefficient; tendency (mechanism) to adsorb; hydrolysis; reactions with highly reactive species (hydroxyl radicals, singlet oxygen, ozone, chlorine and bromine), photolysis and microbial degradation. All these properties should be understood with respect to kinetics, temperature, and effect of catalysts and should be studied both in homogeneous as well as heterogeneous phases.

The contribution by Stone is obviously of interest and should be encouraged since "natural breakdown mechanisms" will be extremely important both in terms of understanding chemical response times to decreases in pollutant discharge but also for indicating directions of industrial treatment processes.

808272 James Pankow - Migration of Organic Chemicals in Groundwaters at Chemical Waste Disposal Sites

Summary: By-products of a variety of chemical processes are often disposed of in mixtures and chemical disposal sites. Pankow et al provide a logical approach to evaluate the rate of dispersion of chlorophenols in both saturated and unsaturated groundwater systems. They first characterize the flow regime in detail. They then measure the concentration, both dissolved and adsorbed, of chlorophenols in the groundwater. Finally, with partition information from laboratory studies, they model the dispersion.

Comments: Groundwater contamination at chemical waste disposal sites is a serious problem nationally. This type of research is valuable because it provides a strategy to evaluate the extent of contamination as well as a strategy for possible cleanup. It is also especially valuable since it provides a data base where mixed chemicals are involved. Most laboratory data, and most models, deal mainly with single solute transport.

808779 Vera Alexander: Effects of Crude Oil Spills on Northern Stream Invertebrate and Periphyton Communities

Summary: Little information on the ecological effects of crude oil in far northern latitudes exist. Through seven years of experiments, the authors found that invertebrates were very sensitive to crude oil and that the elimination of zooplankton shifted grazing patterns on phytoplankton which, in turn, affected the type of phytoplankton.

Comments: Oil spills are a great threat to ecosystems at all latitudes. A quantitative assessment of the effects under arctic conditions is obviously desirable if one is to predict response and clean up methods to spills in these ecologically fragile regions.

807081, 810219 Steven Wofsy - Nitrification and Exchange of Dissolved N_2O and O_2 in Polluted Estuaries; Chemistry of Fixed Nitrogen in Polluted Estuaries

Summary: Many rivers and coastal waters (estuaries) serve as receptors and treatment facilities for nutrients, which, in turn, may be derived from treatment facilities or be of natural origin. The nutrients strongly influence phytoplankton production, which then influence the state of

eutrophy. Wofsy's work deals with the behavior of N and P at the river/estuarine interface. The research group derive relationships for adsorption, desorption and transformation rates of these nutrients for some major rivers in the U.S. and for the Amazon River.

Comments: This information is essential for understanding not only water quality issues with respect to state of eutrophy, but also for understanding the fate and transformation of trace xenobiotics and metals. These will often partition into phytoplankton and most environmental fate models require information on phytoplankton biomass and production rates.

812657 C-C Tsai - Aqueous Solubilities of Organic Pollutants and Related Compounds

Summary: Activities in pharmacology, chemical engineering and environmental science need information on physical and chemical properties of compounds. As far as environmental transport is concerned, aqueous solubility is one of the most important properties to know. The literature does not contain much information on this property for many substances of environmental interest. A larger data base is clearly needed. Since we are literally talking about hundreds of thousands of compounds, we need the ability to accurately predict solubility using a minimum of input information (e.g. structure, melting point, boiling point). This research adds an important approach to this area of endeavor. QSARs are used in this approach. Molecular descriptions (molecular surface area, volume, etc.) are found to correlate quite well, although the theoretical foundation is not yet well developed.

Comments: This research falls in the same category as that of Stone.

That is, the ability to predict a property is essential. In this case, such an ability will be important for a variety of disciplines, i.e. pharmacology, chemical engineering, chemistry and environmental fate modeling.

4. GROUNDWATER TRANSPORT AND FATE

4.1 Introduction

A variety of federal agencies support research related to groundwater transport and fate of contaminants. Consequently, it is critical that EPA focus its research efforts on areas that specifically support its mission and that are not being adequately pursued by other agencies. The program has attempted to attain this focus by concentration on three areas:- (1) the analyses of transport and fate of contaminants in the unsaturated zone, (2) the strengthening of the linkage between experimental laboratory assessment methodologies and real world problems, and (3) the development of methods to assess the effect of biotransformation on toxics in groundwater.

In summary, ERP efforts in groundwater transport and fate have been carefully focussed to yield the largest advance in knowledge in the areas needing the most attention at the lowest cost. Contributions have been made in all subjects that are necessary to evolve a reliable transport and fate modeling framework. In addition, special attention has been directed to a specific problem content that is essential to EPA's mission of evaluating the impact of land disposal on the nation's groundwater resources -- the unsaturated zone.

4.2 Modelling the Unsaturated Zone

Although much research has been devoted to understanding and simulating the transport and fate of toxic substances in aquifers, much less is understood about unsaturated groundwater. This lack of understanding represents a severe shortcoming for the EPA and other agencies that are mandated with evaluating the effect of surface-applied contaminants on groundwater. The unsaturated zone, which lies between the surface and the water table, represents the weak link in establishing cause-effect relationships for problem contexts ranging from pesticide application to land fills. It is of particular importance because it is the probable site of most of the biological transformation that might act to modify the composition of toxicants as they transit from the point of application to the potential consumer. For this reason, ERP has supported two major research efforts to understand and predict the movement and reaction of contaminants within this zone.

Because of the lack of knowledge in this area, the research efforts are of a fundamental and exploratory nature. The first deals with basic laboratory and field work to gain an initial understanding of the behavior of unsaturated zone flow. The second deals with the development of the basic modeling framework that will be needed to make predictions of the transport and fate of toxicants in this complex environment.

[Grant #812919]

Glass and his colleagues at Cornell have mounted lab and field investigations to advance understanding of what has been termed the

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wetting front instability problems. This phenomenon, also called "fingering", involves the short circuiting of toxics through the unsaturated zone. The Cornell group has developed both laboratory and field experiments to gain insight into this mechanism. These experiments addressed two major questions: (1) under what circumstances does fingering occur? and (2) once the flow field has become unstable, how can its behavior be described in terms of relevant system parameters?

The lab study yielded several important insights. First, the wetting front manifested a wavy structure with wave amplitude increasing with time. Second, the effect of heterogeneous distribution of soil moisture at the onset of an experiment has a profound effect on the evolution of fingering. Finally, these heterogeneities acted to amplify rather than attenuate flow field instabilities.

The field studies tended to verify that the lab observations also occurred in the environment. In particular, heterogeneities were more prevalent in the field and, thus, had an even greater effect on fingering than had been observed in the lab.

The Cornell studies of the unsaturated zone have established a sound and strong foundation upon which future research can be based. In particular, the fundamental insights will have a major bearing on the structure of mathematical models that will inevitably be developed to make predictions of the dynamics of the unsaturated zone.

[Grants #811528 and 810156]

Aside from lab and field studies, the other major effort to gain predictive capabilities in the unsaturated zone deals with the development

of mathematical models. Germann and colleagues have made several contributions in this area [810156, 811528]. These involve both models to simulate water flow alone [810156] and flow along with a pollutant--specifically, bacteria. In both cases, the investigators have based their models on the pneumatic wave approximation. This approach is a standard modeling technique that has been successfully implemented in other problem settings. Aside from deriving the mathematics, Germann et al have made contributions related to the measurements that will be necessary to effectively calibrate the approach to groundwater problem contexts. Their work is also useful in suggesting experimental designs for extending and refining the model.

4.3 Laboratory Models for the Assessment of Transport and Fate of Toxicants in Groundwater

Forging a sound linkage between well-designed laboratory simulations and actual groundwater systems depends on two key factors. In particular, the laboratory apparatus must capture the essential features that characterize the behavior of the environmental system. Second; accurate and economical mathematical models must be designed to extrapolate lab results to make predictions vis a vis the real problem setting. The Program has supported two efforts that have resulted in major contributions in these areas.

[Grant #809464]

Hutzler, Crittenden and their colleagues at Michigan Technological University, have developed a unified laboratory/modeling approach for

investigating the transport and fate of toxic compounds in saturated groundwater systems. This work is noteworthy in the close coupling between the lab and model application. Additionally, it has resulted in the integration and subsequent refinement of state-of-the-art chemical engineering methodologies into the groundwater quality assessment arena. In particular, a very efficient solution technique, orthogonal collocation, has been used to obtain simulation results in an extremely economic fashion.

[Grant #810819]

There are a variety of mathematically-oriented problems that are relevant to the effective modeling of transport and fate of contaminants in groundwater. These have important implications for the interpretation of both lab and field information. Parker, of Virginia Polytechnic Institute, **[810819]**, has made several significant contributions to clarifying and formulating vigorous solutions to these problems. Two of these have been supported by the ERP.

First, two related but different modeling perspectives are employed to characterize solute transport in porous media: volume - and flux-averaged concentrations. Parker has demonstrated that perceived limitations of the convective dispersive model for media with large variation in pore water velocities may, in certain cases, be attributable to failure to properly distinguish between these perspectives. These limitations are often due to misapplication of boundary conditions.

Parker's second contribution involves the development of proper averaging techniques for characterizing the effect of flow perpendicular

to layered porous media. The approach involves the use of time convolution to predict breakthrough curves under certain simplifying assumptions. Among other things, this approach rationalizes, simplifies, and reduces the cost of simulating such systems without sacrificing accuracy.

4.4 Effect of Biotransformation of Toxics in Groundwater [Grant #808034]

Much of the emphasis of research on groundwater contamination has focussed on the physics of transport. Of equal importance are the chemical and biological reactions that act to transform toxic substances in groundwater. In particular, transformation by microorganisms appears to be the only process that can bring about significant transformations within a time frame of a few years. Although significant research has been devoted to biodegradation of toxic compounds in water treatment and laboratory settings, little has been done to advance understanding of the process in subterranean environments. Investigators at Stanford University [808034], with the support of ERP, have been at the cutting edge of research in this area.

This research has yielded a number of important results. It has demonstrated that transformation of certain organic compounds occur under both denitrification and methanogenesis. This is significant because both mechanisms can occur due to microbial action in soils and groundwater. Transformation times were estimated for both processes. In addition, the biochemical pathways and mechanisms governing the transformations were partially elucidated. These insights will contribute to future research

in the area. Beyond the specific experimental results, this research also has resulted in the development of a theoretical framework and conceptual model of the process of biotransformation in the environment. This model is due both to the experimental results as well as the extensive experience of the Stanford group in related areas, such as biofilm processes in waste treatment.

[Grant #811809]

A critical aspect of classical water quality modeling is the determination of model coefficients. In essence, modeling can almost be counter-productive if it is not based on accurate and reliable coefficients. One of the weakest links in the process is the estimation of reaeration rates of dissolved oxygen in estuaries. Presently available methodologies are either procedurally difficult, rely on major assumptions, ignore important mechanisms or are not suitable for estuaries. In the latter category, tracer-gas techniques would be of great utility but are only applicable to streams and rivers. Holly and Bales **[811809]**, of the University of Texas, have modified the tracer-gas method so that it can be used to obtain reasonable estimates for estuaries. They accomplished this objective by addressing the methods major limitation -- that is, that it is not designed for the density-stratified flow regimes that are typical of estuarine environments. The major step in this effort was the development of the proper mathematics to extract the reaeration rate estimate from the tracer-gas experiment. Holly and Bales derived a simple-to-implement but physically realistic procedure to do this. They then verified their approach by comparing it

to a much more rigorous numerical model of the process. In this way, they have provided water quality analysts with a methodology to economically estimate this parameter. Beyond its utility in predicting the effect of sewage on estuarine oxygen levels, the method has added significance because it is also useful in assessing the impact of volatile toxicants on estuaries. This is due to the fact that oxygen serves as an analog for certain significant toxicants.

5. APPLICATION OF ANALYSIS, PROCESSES, FATES AND TRANSPORT TO INDUSTRIAL WASTES

Grant #807915

This research utilized soil interaction and transport information discussed above and developed models for predicting the transport of metals from industrial wastes through soils. It is important to note that this research was supported before the "Super-Fund" concept was developed, but it has all of the aspects required for first class efforts in this area. Fuller went further to develop various designs for impermeable soil layers for holding of wastes. He also assessed problem areas for future research.

Practical outcome of this research resulted in two very significant EPA reports: "Liners of Natural Porous Material to Minimize Pollutant Migration" (EPA-600/S2-81-122 July 1981), and "Methods for Conducting Soil Column Tests to Predict Pollutant Movement." (EPA-600/9-82-002 MERL), in addition to many peer-reviewed literature studies.

The results from the above grant perhaps summarize aptly the

importance of analysis, speciation, transport and application of these studies to waste containment.

United States Environmental Protection Agency
Office of Research and Development Washington, DC 20460

EPA

Research Grants Program

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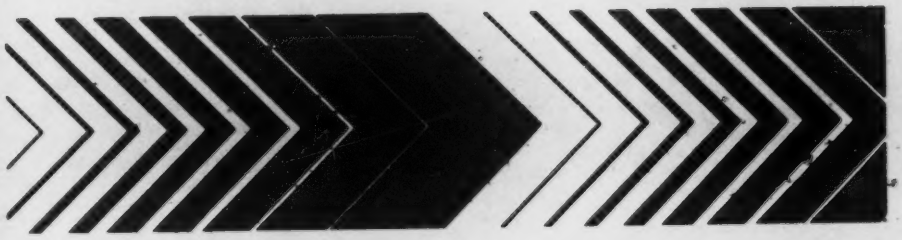

PREFACE

The U.S. Environmental Protection Agency's Office of Research and Development (ORD) established the Research Grants Program within the Office of Exploratory Research (OER) in 1980. The objective of this program is to develop an effective means to stimulate extramural scientists to work on EPA's technical problems, to complement existing EPA programs and to provide a stronger creative base for mission-oriented research needed for the Agency's regulatory and enforcement purposes. To date, through its Research Grants Program, OER has supported approximately 600 research projects in priority areas of enviornmental health, environmental biology, environmental engineering, environmental chemistry/physics (air) and chemistry/physics (water).

In October 1987, OER initiated a reivew and evaluation of the investigator initiated research grants program. This was accomplished by two mechanisms. One was an idependent assessment conducted by the American Management System of the program's role in Federal environmental research, and to identify opportunities for improvement. The report of this assessment is avaiable from OER. The other was the preparation of reports by the Chairmen of peer review panels on the impact of the competitive research grant program in their discipline area. This is one of those reports.

Evaluation of the Projects Suppoted by the Program in Environmental Health

Report prepared for the

Office of Exploratory Research
U.S. Environmental Protection Agency

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General Introduction

The mission of the grants review panel of EPA-Health Effects is to support peer reviewed basic research that will address the present problems in risk hazard, at-risk exposure and to develop new methodologies and new interpretations of the results of chronic and acute exposure to putative environmental toxic substances. This basic research will by its nature reduce the uncertainty associated with assessment and management of the risk following acute or chronic exposure.

The acute and/or chronic exposure to environmental toxic substances requires hazard indentification and addressing the public's perception of the interpretation of data of at-risk-exposure, risk assessment and risk management. In this context the direct and indirect routes of exposure of humans need to be evaluated and the biological consequences of these exposures also evaluated. Examining protocols for regulating exposure to genotoxic and nongenotixic substances when an insult delivered to a cell is not obvious and no point mutation results must be effective in reducing the hazard in the environment. It must be realized, however, if activation of a proto-oncogene takes place, how does risk management deal with at risk exposure and quantitation of these environmental toxic substances? These uncertainties should be addressed by basic research. These at risk exposures to such nongenotoxic compounds cannot be evaluated using standard-at-risk-technology. It has been suggested that the expanded understanding of the molecular events of cancer and other health related dysfunctions such as changes in cell-to-cell communication could offer a way to reduce uncertainity of exposure to these environmental nongenotoxic substances.

Recently it is of interest to note that Dr. David P. Rall, Director of

NIEHS, in the December, 1987 issue of the AIHC Quarterly (American Industrial Health Council) recommended that quantitative risk assessment needs to be in place to address issues that the community faces when at risk to all environmental toxic substances. However, recently, Dr. Stuart Aaronson, Chief of the Laboratory of Cellular and Molecular Biology - NIH-NCI, in collaboration with Drs. Reynolds, Stowes, Patterson and Anderson of the Laboratory of Biochemical Risk Analysis of NIEHS suggest that "The ability to distinguish between promotion of background tumors versus a genotoxic mechanism of tumor initiation by chemical treatment would aid in interpretation of rodent carcinogenesis", (Science, September, 1987, pg. 1309-1316). In this vein, nongenotoxic compounds that do not induce mutations in the Salmonella assay but did activate the ras gene in situ, ergo a transformed phanotype is expressed, could be used to evaluate this class of environmental toxic substances. In this situation and numerous other short term and long term quantitative assays that do not and, will not identify quantitatively carcinogens that activate oncogenes in this fashion, other systems need to be evaluated to determine the at risk hazard to human health. These same problems also exist for environmental exposure to neuro-toxic substances; non-genotoxic substances that can suppress the peripheral and/or cellular immune system; and lastly, depress in an irreversible fashion the differentiative functions associated with organs that maintain homeostasis.

It is the professional opinion of the EPA Health Effects Grants Review Committee that the General Solicitations Program has for a number of years supported basic research to reduce the uncertainity of hazard identification and risk assessment with the goal of human relevance and human exposure and risk assessment as our overall objective and has contributed significantly to

the Agency's mission. We summarize our results to date in this report:

PART ONE: MECHANISTIC STUDIES DESIGNED TO INVESTIGATE THE REDUCTION OF UNCERTAINTY OF AT-RISK-EXPOSURE

Introduction

A substantial portion of the research supported by the Office of Exploratory Research of U.S. Environmental Protection Agency deals with basic studies on the induction of mutations and cancer by environmental agents as well as with the development of methodologies, based upon this newly acquired knowledge, for hazard identification and risk assessment purposes. As highlighted below, from the results of selected studies, the program was highly successful not only in generating fundamental information but also in developing powerful methods that uniquely bear on the risk assessment process.

Mechanistics Studies

Genetic studies on the fruit fly Drosophila have a long and distinguished history and indeed the Drosophila mutagenicity test is widely used for hazard identification purposes. However, in spite of its widespread use, the molecular basis of induced mutations and their repair in Drosophila is not well established. This is a serious deficiency if results with Drosophila are used to assess risk to the germ cell or risk of cancer in humans. Thus, if the induction, processing and repair of DNA is different in Drosophila than it is in mammals and especially humans, then the usefulness of that system is questionable. The fundamental dilemma was addressed at the organismic and molecular levels in an elegant series of studies at Emory University which were subsequently transferred to Southern Methodist University. It was established in those studies that indeed the spectrum of genetic responses in Drosophila is consistent with molecular mechanisms operative in mammals and

even humans. Having established this similarity, the investigators are using molecular probes to determine whether the details of the chemical specificity of induced heritable changes are also identical in Drosophila and higher forms of life. Thus far the results indicate that indeed there is similarity between these processes and hence this validates a very important tool used in hazard identification.

Mechanism of Action of Environmental Agents and Serendipity

A series of studies carried out at Case Western Reserve University on the basis of the action of nitrated polycyclic aromatic hydrocarbons (nitroarenes) had a far reaching impact not only on the study of thee mechanism of action of these widely distributed mutagens and carcinogens but also on broader aspects of hazard identification and risk assessment. Thus these EPA supported studies resulted in the development of a simple assay for the detection of these chemicals in environmental samples, such as airplane emissions, ambient air particulates, emissions from incinerators, wood ovens, kerosene heaters and cigarettes, underground dieselized mines, prepared foods, river sediment, soil samples, etc. The detection and quantification of these chemicals in environmental samples has permitted a better understanding of the magnitude of the environmental hazard posed by them.

The study also elucidated some new steps in the enzymic transformation of these substances which serves to explain why some members of the group are endowed with extraordinarily potent biological activity. This new understanding is directly applicable to the action of aromatic amines, another class of important environmental and industrial chemicals.

However, beyond these findings, the studies led to two other important ramifications of more general applicability. Because early in the study of

the biological properties of nitroarenes it was found that some members of the group possessed unusually potent mutagenicity while others were essentially devoid of such activity, and because these differences could not be explained nor predicted by the available methods to study structure-activity relationships, the investigators developed an entirely new approach to structure-activity predictions based upon artficial intelligence. This method is currently being evaluated as a predictive as well as mechanistic tool by the U.S. Environmental Protection Agency, the National Toxicology Program and others. As an unexpected benefit, it is also being used in the design of pharmacologically active molecules to optimize beneficial activities and decrease toxic side effects.

Additionally, the fact that in excess of 200 nitroarenes have been recognized in the environment very quickly led to the realization that it would not be practical nor feasible to test all of them for carcinogenicity in the traditional rodent bioassay. This suggested the use of combinations of short-term tests. However, in order to use such tests in a predictive manner, it was also quickly realized that new algorithms would have to be developed to assemble such batteries of tests and to interpret the results in a quantitative manner especially since both positive and negative results can be expected. This led to the development of CPBS, the Carcinogenicity Predicition and Battery Selection Method. CPBS is based on Bayes' theorem and basically states that different tests have different performance characteristics and these must be taken into consideration when analyzing and interpeting the results of such tests as well as in assembling batteries of such tests. The present version of CPBS is greatly refined and is available for use on a personal computer. In addition to its application for research

purposes, CPBS has now been used in a number of recent regulatory situations in which the results of short-term tests needed to be interpreted. It is now routinely being used in the early decision-making process in product development.

Risk Identification

Short-term tests have been employed to identify potential cancer-causing agents. These tests, which are rapid and cost-effective, have been widely used. However, as the nature of the chemicals being tested became more diverse, the concept that carcinogens are mutagens has undergone challenge as being too simplistic. A project supported by the Office of Exploratory Research of the U.S. EPA at the University of Texas Medical Branch at Galveston has provided the evidence as well as the intellectual stimulus to reexamine the oversimplistic approach that relies solely on *in vitro* assay. The "Combined Testing Protocol" developed and pioneered by these investigators uses *in vitro* and *in vivo* assays. This approach has now been widely accepted and has been incorporated into many protocols including those of the U.S. National Toxicology Program.

Early Markers of Cell Transformation

As mentioned earlier, the multitude of short-term tests complicate the interpretations of test results as well as raise questions regarding their relevance to carcinogenesis. Biologically, however, the oncogenic cell transformation assay has been accepted as relevant since the endpoints, including the ability of cells to grow as tumors in animals, bear a direct relationship to cancer progression. The drawbacks of cell transformation assays derived from the fact that they are time-consuming, frequently require specialized equipment, and hence are expensive. An EPA-sponsored study at the

University of Southern California sought to develop both morphological and immunological markers that would permit the early identification of transformed cells. This would not only permit a wider use of the assay, with a concomitant decrease in cost, but it would also allow studies of the events that take place during the early stages of the in vitro oncogenic transformation process. Such knowledge is obviously applicable to an understanding of cancer initiation and promotion in animals. The investigators were successful in identifying early markers of cell transformation such that the assay can be carried out within a 9 day period. Further validation of this new assay would be extremely beneficial in that it would permit a large number of chemicals to be tested and thereby leads to a better evaluation of the applicability of cell transformation assays as predictors of carcinogenicity in mammals and humans. Additionally, however, it will make possible studies to dissect, in a relevant biological system, the various steps involved in oncogenic transformation.

DNA Damage/DNA Repair/Exposed Populations/Risk Qualification

For most chemicals, modification of the cellular DNA is the first step in the induction of mutations and cancers. Heretofore, most studies to elucidate the mechanism whereby this occurred have been done in rodent systems. The applicability of these systems to risk assessment in humans is, of course, a matter of concern as well as of debate. Investigators at The Ohio State University have been studying the activation and detoxification of chemicals representative of chemicals present in soot (polycyclic aromatic hydrocarbons) in cultured human lung and skin cells, these cells represent the tissues that are the points of entry of most environmental toxicants. The investigators found that these cells handled these substances in a novel fashion which

resulted in a new type of DNA lesion. Since the processing of DNA damage (see below) is influenced by the nature of the lesion, this is a most important finding which needs to be taken into consideration in the risk assessment process. Additionally, these researchers found that the distribution of the biologically significant lesions along the DNA was not a random one. Since many mechanistic studies are focused on cumulative effects on the DNA, they may overlook the ones that act at especially susceptible sites. The findings by these investigators, therefore, provides an additional measure of the complexity of the cancer initiation process and suggests that future studies concentrate on specific portions of the genetic material.

Sensitive chemical, immunological and biological methods are available to detect damage to the DNA such as DNA adduction by environmental mutagens and carcinogens or their metabolites. However, a number of studies have shown that DNA adduct formation, although the primary lesion, is not in and of itself an injuricus event that leads to heritable changes and that induces cancers. Rather, the crucial step may well be the one that involves the processing of this damage. An EPA-sponsored study at the University of Washington in Seattle has been investigating this possibly pivotal process and set out to test the hypothesis that when lesions in the DNA are removed they create a nucleotide "gap" which, when filled by another nucleotide initiates the mutagenic or genotoxic event. Through a series of elegant experiments, the investigators did indeed demonstrate the transient presence of such gaps which are then filled by the incorrect nucleotide. This finding may also provide a basis for the unusual spectrum of mutations induced by a number of environmental agents. Additionally, an assay was developed to quantify the presence of such gaps in DNA and thereby provide a method to both determine

human exposure to carcinogens and mutagens as well as to study the ability of individuals to repair these gaps and thereby identify persons at risk for cancer because of deficiencies in their repair mechanisms.

In complementary studies carried out at The Ohio State University, the ability of human cells to repair damaged DNA is also being studied. That investigation takes advantage of the almost unique expertise developed by the researchers to maintain human epithelial cells in culture, these are the progenitors of most human tumors. By determining the level of DNA damage and DNA repair enzymes in epithelial cells derived from various tissue, the investigators are able to assess the risk posed to specific organs of exposure to different agents. Obviously, this type of information brings an unprecedented refinement to human risk assessment.

Studies supported at the Lawrence Livermore National Laboratory have provided significant insight in the mechanism whereby human cells respond to insult by mutagens and carcinogens. In parallel, a number of imaginative as well as extremely useful methods to recognize chemicals endowed with mutagenic and carcinogenic potentials and to identify exposed populations and quantify the possible risk have been developed.

Thus in one instance, the EPA-supported study led to the development of a highly sophisticated assay to determine the number of mutant red blood cells in humans following exposure to mutagens/carcinogens used in cancer chemotherapy. Upon method validation, this assay was applied to the study of occupationally-exposed populations as well as to cigarette smokers. Both of these populations exhibited increases in the number of varient cells.

Finally, the method was recently applied to survivors of the atomic bomb at Hiroshima and a correlation was found between the estimated individual

radiation dose and the frequency of mutant cells. It must be noted that this population was studied more than 40 years after the insult. Very recently this method was used to study blood samples from individuals exposed to high energy radiation at the nuclear power accident in Chernobyl. The analysis showed an effect similar to that exhibited by A-bomb survivors, that is, an elevation in the recovery of mutants as a function of dose.

Obviously, these are examples of the application of basic scientific principles to the direct estimating of human risk.

Genetic and Congenital Effects in Humans

While the studies at the Lawrence Livermore National Laboratory dealt with estimation of the possible carcinogenic risk of exposed human populations, investigations supported at South Dakota State University were concerned with genetic and congenital risks such as heritable mutations, spontaneous miscarriages, birth defects and reduced fertility. To that effect a powerful flow cytometric procedure was developed to study the genetic material of sperm. This method has been validated with rodents exposed to mutagenic substances and bulls differing in fertility. Promising, albeit preliminary, results have also been obtained with humans undergoing cancer chemotherapy regimens or attending infertility clinics. The further validation of this highly sensitive method for detecting humans at risk could have a dramatic impact not only in understanding and evaluating this risk but also in elucidating repair or recovery mechanisms and hence could provide invaluable insight on timing of conception for those at such risk.

Epigenetic Agents/Tumor Promoters

A striking example of how the results of basic studies fundamentally affect our perception of complex biological phenomena and also have a profound

impact on risk identification and assessment is shown by the EPA-sponsored studies carried out at Michigan State University. Thus, while early studies indicated that the cellular DNA was the primary target in cancer initiation, subsequent studies led to the realization that chemicals which do not have DNA as their target could also be involved in tumor causation. Such chemicals have sometimes been called "epigenetic". The investigators at Michigan State University reasoned that perhaps these agents acted by interfering with intercellular communication, an important regulatory mechanism. They proceeded to demonstrate such an inhibitory effect under carefully controlled conditions and this, in turn, led to the development of a series of sensitive in vitro assays to demonstrate this effect. Ultimately this resulted in the recognition of a new class of environmental chemicals which possess the ability to inhibit intercellular communication. Disturbances of this phenomena have not only been implicated in cancer causation but in some reproductive and neurotoxic disorders as well. The EPA-sponsored studies have led to current risk assessment models which incorporate the inhibition of intercellular communication as an integral component. This is exemplified by a recent EPA Workshop on the Development of Risk Assessment Methodologies for Tumor Promoters.

Human Consequences of Depletion of the Stratospheric Ozone Layer

Recently, concern has been expressed regarding the possible consequences of ozone depletion on human health. The Office of Exploratory Research of the U.S. Environmental Protection Agency supports a number of studies dealing with possible human sequelae of increased exposure to ultraviolet B-radiation resulting from such a depletion. The results of these investigations indicate that small increases in the ultraviolet rays reaching the surface of the

earth, as may be expected during recreation activities, may indeed pose a serious human hazard. Thus, a study at Case Western Reserve University demonstrated that low doses of ultraviolet B inhibit the immunological function of human monocytes including a blockage of the production of interleukin-1, a substance playing a pivotal role not only in the immune response but which orchestrates the body's resistance to infection and to other toxic stimuli.

A study conducted at Moorehouse School of Medicine examined the possible effects in the change in the wavelengths of ultraviolet light reaching the earth's surface, as might occur as the result of the depletion of stratospheric ozone, on the ultraviolet stimulation of skin thickening. This, in turn, could result in a protective effect by reducing penetration of this form of radiant energy into deeper tissues.

Studies at the M.D. Anderson Hospital and Tumor Institute of the University of Texas System Cancer Center investigated the relationship between exposure to ultraviolet rays and cutaneous malignant melanomas, a form of human cancer, the incidence of which is rapidly increasing. The investigators, also using a mouse model, provide direct evidence that the growth of this type of cancer is accelerated as a result of exposure to ultraviolet radiation. The dose of ultraviolet radiation required to promote the growth of malignant melanomas was surprisingly small, corresponding to between 4 and 12 cumulative hours of sun exposure at a latitude of 30° north. Turning to the basis of this phenomenon, the researchers were able to show that growth promotion was the result of the induced ultraviolet production of a melanoma growth promoting factor.

The above studies add an alarming dimension to the possible human

consequences of the depletion of the ozone layer, namely, the prediction that even moderate increases in exposure to ultraviolet rays will be associated with a considerable increase in the incidence and mortality due to cutaneous malignant melanomas and that this exposure will be accompanied by a decrease in the efficiency of the body's immunological as well as homeostatic defense mechanisms.

Conclusions

Systems used to evaluate at-risk-exposure of humans to environmental genotoxic and non-genotoxic (promoters) substances should present a cross-section of data that will permit quantitative and/or qualitative (promoters) evaluation of the consequences of acute or chronic exposure. The basic research supported to date by the EPA grants mechanism has contributed significantly in an innovative fashion to providing data that has contributed to the reduction in uncertainty in interpretation and designation of a hazardous substance in the environment. Many of the projects presently supported in this section will contribute to our future data base so regulatory assessments can be implemented with a reduced concern for uncertainty associated with the decision.

Part Two: ORGAN RESPONSES TO ENVIRONMENTAL TOXIC SUBSTANCES (Pesticides, Atmospheric Pollution, Neurotoxic-Substances)

Pesticides

Introduction

Pesticides are among those classes of compounds ubiquitous in the environment. Unlike many other environmental contaminants, however, their distribution is both deliberate and necessary for the effective production of food and fiber. It is self-evident, therefore, that more efficient regulation is necessary, not only to restrict the use of compounds with deleterious effects but also to permit the effective use of safe and needed compounds.

Studies supported under the Health Effects Grants Program have expanded our knowledge of pesticide toxicity and have contributed significantly to risk assessment decisions. They include the following typical projects:

Cardiovascular System-Teratogenic Effects

A series of publications have resulted from studies of Grabowski and associates (R808938-010). These include further examination of the cataractogenic effects of mirex but, more important, they characterize in detail the effects, on the cardiovascular system of the offspring, of mirex administered to the mother. It is clear that quite moderate, even low, doses can have profound effects, from death to impairment of heart function. Doses of mirex as low as one-tenth the no observed effect for visible malformations lead to readily detectable cardiac dysrhythmias. These dysrhythmias and their associated respiratory problems are frequently lethal. The late fetal period is the time of maximum sensitivity, rather than the period of major organogenesis, as might be expected, emphasizing the need for precisely timed

tests.

These studies make two things clear, that teratogenic effects cannot be determined from anatomic changes alone and that physiological parameters can be monitored effectively in the newborn test animal. The determination of how general this effect may be among pesticides is still much needed information,particularly since dysrhythmias are common in human babies and may, possibly, be due to prenatal toxic exposure.

Pancreas

Neurotoxic effects of pesticides mediated through the inhibition of acetylcholinesterase are fairly well understood and, if these were the only effects, the regulatory methods currently available would be adequate. However, other effects are either known or suspected, making regulation more difficult. One study supported by the grants program (R808516-010) involved a side effect of organophosphate poisoning noted in human cases, namely pancreatitis. Dr. Goodale and his associates in a series of studies that started with the documentation of the effect in humans, progressed to a determination of the mechanism in several animal models. They concluded that inhibition of a pancreatic butyrylcholinesterase leads to cholinergic stimulation of the acinar cell. Cats lack this enzyme in the pancreas and do not show the effect.

Liver

Many of the deleterious effects of pesticides, other than those related to their pesticidal mode of action, have been reported as occuring in the liver. Due to the central role of the liver in xenobiotic metabolism such effects are also probable loci for interactions beteen xenobiotics. Such interactions are at the heart of many regulatory dilemmas and a great deal of

long term research will be necessary before they can be resolved. Two projects supported by the grants program can be used as illustrations.

A project (R812402-010) on the differential toxic effects of benzidine congeners has been most productive in delimiting their role in lipid peroxidation as well as their activation by both cytochrome P-450 isozymes and by peroxidative mechanisms. The role of lipid peroxidation in many different types of toxicity, from mutagenesis to cell necrosis, makes this an important avenue of exploration. It might also be noted that S9 fractions prepared from the livers of animals pretreated with dichlorobenzidine increased activation of dichlorobenzidine in the Ames test more than S-9 fractions from the livers of animals treated with 3-methylcholanthrene (3-MC), phenobarbital or Arochlor. This latter finding illustrates that the routine use of S9 fractions from 3-MC treated animals may not always be the best practice.

A second project (R811072-010) on the lethal interaction of toxic chemicals has also been most productive. Most of the publications resulting from this project have dealt with the dramatic potentiation of carbon tetrachloride toxicity by chlordecone, but other interactions have also been examined. Recently these studies have been extended into examination of the effects on liver regeneration and, most recently, into the role of calcium in the toxic interaction. Significantly greater increases in cytosolic Ca+2 levels, indicative of irreversible cell damage, were seen with chlordecone and carbon tetrachloride than with carbon tetrachloride alone. These studies, initiated by the grantee, Dr. Mehendale, have stimulated much additional work in other laboratories, particularly those of Plaa and Recknagel.

Conclusions

In addition to providing much new information in areas of toxicological

importance these studies are illustrative of those supported on an important group of environmental contaminants regulated by the EPA. They have stressed the importance of interactions and may be used as models for many pesticides currently in use or for new compounds. There are other benefits of an indirect nature noted below.

Air Pollution-Human Studies

Introduction

Although the dangers of air pollution appear to be manifest, and regulation of air quality mandated, there are still numerous pitfalls for the regulatory agency, the USEPA. Many of these uncertainties reside in the difficulties of carrying out epidemiological studies in which one of the variables is the ambient air. Other difficulties lie in the complex machinery of pulmonary function, the problems of finding the most suitable of the many tests of pulmonary function and the ever-present difficulty of extrapolating from experimental animals to humans. In the case of pulmonary function there are often large anatomical, as well as biochemical, physiological and functional differences. This area, in general, has been one of the most active for the grants program and in this report only a few projects have been singled out as illustrative of the projects supported. The overall theme of the report is the studies on humans but it should not be forgotten that the program has also supported valuable animal studies including the following: R808267 and R811494 on the interactive effects of formaldehyde and ozone; R809091 on cadmium oxide toxicity in the rat; R809104 on interactive effects of metal oxides and sulfur dioxide; R812869 on interactive effects of nitrogen dioxide and ozone.

Human Studies

A long series of studies (The UCLA Population Studies of Chronic Obstructive Respiratory Disease) supported in part by R808620 have established that chronic exposures to a mixture of photochemical oxidants, sulfates and particulates are associated with increased loss of lung function. Although early studies implicated dysfunction of the large airways it was clear that tests reflecting small airway function were effective at demonstrating this functional loss. Interaction with cigarette smoking was also investigated in these studies. These studies also addressed several crucial issues in selection of appropriate tests for studies of chronic obstructive respiratory disease including: sensitivity and the potential to identify impairment while reversibility might still be possible; feasibility and the need to administer to a large population; acceptibility and toleration by the population to be tested.

In other studies on the effect of ozone (R807723) on pulmonary function in children a small, but significant, effect on respiratory mechanical function was indicated. R808738 supports studies on the effect of ozone on asthmatics, a subject of some importance since asthmatics may represent a high risk groups for air borne pollution.

A series of studies supported by R807515 on the effect of diesel exhaust on railway workers supports the hypothesis that occupational exposure to diesel exhaust gives rise to a small, but significant, increase in lung cancer risk.

All of the above studies show small differences and are subject to the methodological criticisms frequently leveled at epidemiological studies. However, they include large populations and, in several cases, contributed

significantly to the methodology necessary to define such small differences. It should be remembered that in regulation of air quality, very large populations are potentially at risk, and the resolution of small but significant decrements of lung function or in the expression of carcinogenesis may be of critical importance.

Several projects have been supported that involve experimental work on humans. Such studies were difficult to carry out successfully but critical to the understanding of mechanisms.

Application R809074 supported studies on aerosol deposition in the human oral passage during natural oronasal breathing. These studies indicated that current methods for estimating penetration of aerosol particles through the oral mucosal lining generally produce underestimates.

R810101 supported studies on both deposition and clearance of particulate fractions and the effect of sulfuric acid on clearance. The clearance of ferric oxide aerosols was markedly slowed after exposure to low doses of sulfuric acid, however, the effect was more sensitive to time of exposure than to concentration.

Current studies, under R813049, were concerned with the pulmonary, metabolic and ventilatory responses of older men and women to ozone and nitrogen dioxide. Such studies, as with the studies mentioned above on asthmatics, were critical since they concern a population that might well be at increased risk.

Conclusions

Some of the most vexing regulatory questions with which the EPA is involved relate to the effects of air pollution. They involve effects on large populations, potentially high risk sub-populations and complex

interactions. The studies reported above contribute to knowledge in the area and in such a way as to relate to the regulatory problems. Although the agency itself is well known for research in this area the need is so great that no one single group can even address, much less solve, the outstanding problems and reduce the uncertainty of interpretation.

Neurotoxicology

Introduction

While of potentially the greatest health relevance, neurotoxicology has been one of the least investigated disciplines. In no other organ system is it likely that small amounts of damage can have such long term and widespread consequences. In general, toxicology often has been concerned with frank structural or functional damage to target organs (e.g., the kidney or liver), and environmental and industrial regulations reflect this focus. However, chemicals may perturb the nervous system, producing behavioral, endocrinological, physiological, or other changes without causing gross pathology. Thus, it is critical not only to develop new methods that may help detect such potential toxicants, but also to understand why such changes occur.

While it is clear that such measures are needed, developing the appropriate stock of data, and using this to formulate a useful strategy, has been difficult to achieve. In the ideal, systems available to evaluate at risk identification, used to screen the biological effects of toxicants on central nervous system functioning should be simple, rapid, and inexpensive, and should be able to detect deficits caused by alterations in almost any region of the nervous system. These systems could be used to reduce the

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uncertainty associated with interpretation of the data. Use of such technologies require not just the hypothesis that some particular parameter (behavioral, biochemical, etc.) may be sensitive to insult, but studies that validate this hypothesis. Inevitably, such studies require thorough and fundamental examination of the underlying biology related to the suggested endpoint.Studies supported by the Health Effects Grants Program have provided some of the data needed to these ends, as illusrated by the following projects:

Non-mammalian In Vitro Testing

Audesirk and his associates using pond snail neurons and embryonic chick neurons develop in vitro assays to measure for toxicity. Data illustrating that both types of neurons are sensitive to toxicants which affect sodium channels suggest that this model may have potential usefulness to study variety of neurotoxicants. Of specific interest is the idea it may be useful in determining species differences in responses to specific environmental contaminants.

Non-mammalian In Vivo Testing.

Davis and his associates tested the hypothesis that neurons, while developing or regenerating, are more sensitive indicators of toxic exposure than are mature neurons. They crushed the optic nerve of a goldfish, administered test neurotoxicants, and measure the time course for regeneration of the optic nerve as indicated by restoration of a conditioned response to a visual stimulus. They found that developing axonal neurons are exceedingly sensitive to doses of some neurotoxicants which have no effect on mature cells. They extended this assay to the study of axonal organization in the optic tectum and have found that colchicine (an alkaloid neurotoxicant) can

facilitate the recovery of functional axonal connections by inhibiting the competition of already established axons.

Mammalian In Vivo Behavioral Assays

Another type of behavioral assay has been developed by Fechter and associates, who use the "startle response" to detect the effect of neurotoxicants on audition. Their work tested the hypothesis that this endpoint is more rapid, but equally sensitive, compared to other traditional behavioral measures. Other studies extended this research to examine how carbon monoxide affected sensory and memory systems in animals. An important finding was that prenatal exposure to moderate levels of carbon monoxide produced permanent memory deficits, and neuropathological changes in neostriatal development that persisted well beyond the termination of the hypoxic exposure.

Two projects, (Heise and McMillan) focused on more complex learned behavior and memory. Heise and coworkers tested the effect of pesticides and cholinergic drugs on memory, using alternation tasks and reversal tasks. Because many pesticides inhibit acetylcholinesterase, it was commonly believed that pesticides impair memory through their action on the cholinergic system. However, this group found that four representative pesticides did not affect memory, but rather elicited a nonspecific behavioral suppressant effects. Anticholinergic drugs such as scopolamine, however, impaired specific discrimination and retrieval processes important in memory. Data such as this demonstrated the necessity of separating the specific and nonspecific behavioral effects of toxicants. McMillan and his associates (25-46) conducted extensive studies on the effects of trimethyltin and triethyltin on scheduled controled behavior and their concomitant effects on hippocampal damage in

rats, mice and pigeons. They discovered high correlations between behavioral changes and neuropathology in individual animals.

Finally, Merigan and coworkers performed studies on the effects of neurotoxicants on the primate visual system. Their work illustrated that this system provides a very sensitive measure of neurotoxicity to the involved areas of the nervous system. Such data were essential to the thesis that physiological endpoints may have a utility for testing for important environmental toxic substances.

Pharmacokinetics of Delayed Neurotoxicants

An essential ingredient of neurotoxicology has to be toxicokinetics. As noted for Heise's project, although organophosphorous compounds produce neurotoxicity, the mechanism by which this occurs is presently unknown, and the potency of these compounds vary widely from subject to subject. Hansen explored some of the pharmacokinetic factors which affected the clinical toxicity of these compounds, and found important differences in the bioavailability of these compounds.

Conclusions

These projects presented here were directed toward developing the assays which might detect neurotoxicity of a wide variety of chemicals, as well as providing data important towards understanding such events. However, they also illustrate important lessons in this field. First, is is clear that neurotoxicological risk assessment, at least for the near future, will have to utilize behavioral and physiological endpoints. Several of the funded projects provided data in that direction. However, an essential component of such studies is that these behavioral endpoints be characterized as to neurochemical substrates, including the involved neuroarchitecture. While some

of the funded studies provided data in that direction, there is a need for a longer term, more sustained effort in these basic directions. As a final point, modern neurosciences, of which neurotoxicology is a part, require a high degree of collaborative, multidisciplinary studies. While the research base necessary for regulation may only be acquired slowly, the activities of the Health Effects Grants Program can hasten the pace and contribute in a significant fashion to develop these integrated efforts.

PART 3: NON-GENETIC, IMMUNOTOXIC AND ANALYTICAL METHODOLOGIES TO MEASURE AT-RISK-EXPOSURE

Introduction

A factor in the prediction of human health effects of exposure to chemical carcinogens is the validity of the test systems utilized for risk assessment. Major accomplishments include the development of technology for the utilization of cellular systems from various species that allows direct comparison with human cells.

Trump and his associates have made a comparison of metabolic activation of carcinogens including comparative ultrastructural responses to environmental toxic substances. An example of species comparison is the work by Dr. Diamond and coworkers in which a low passage hamster embryo cell line activation of the carcinogenic polycyclic hydrocarbon 7,12-dimethylbenz(a)-anthracene was carried out. Work of this type is important because cell culture technology has progressed at a rapid pace and the culture of certain non-transformed animal cells in chemically defined media is now possible and is cost effective. In the near future, it should be possible to culture and grow various normal (non-transformed) human cell types in chemically defined media. At the present time, we now have limited success with the culturing of human breast cells in a few laboratories including the laboratory of Martha Stampfer, University of California, Berkeley. With the sudden and unexplained rise in breast cancer today, we need very much to understand the processes and factors, including environmental toxic substances, that may have a role in the induction of human cancer. One can predict that within a decade there will be much less need for animal models for prediction of human response to environmental agents if we are prepared to utilize biotechnology effectively

in the development of human tissue and cell models for prediction of human response to environmental toxic substances.

Immunotoxicological Effects of Environmental Agents

Immunotoxicity is beginning to be recognized as an important aspect of the effects of chronic exposure to environmental agents. The integrity of the immune system during and after such exposure is a part of the routine toxicity assessment of many chemicals. Exposure to such immune modulators can affect human health by provoking existing disease or by rendering individuals more susceptible to diseases such as autoimmunity, carcinogenesis, and even infections. An example of the importance of understanding the effects of trace contaminants in major industrial chemicals are the findings of Kerkvliet and coworkers concerning the immunotoxicity of technical grade pentachlorophenol in mice. Further investigation has shown that the contaminant 1,2,3,4,6,7,8- hepatochlorodibenzo-p-dioxin induces humoral cell regulation. Such studies are just the beginning to what can be predicted to be a major component of the overall toxicity effects of environmental agents with a high degree of complexity due to the individual differences in the human immune system.

Mechanisms of Cellular Effects of Heavy Metals

Heavy metal toxicity involves more cellular components and processes than another type of environmental agent toxicity. Such a diverse range of toxic effects means that the study of mechanisms is essentially different in each research laboratory and thus agreement upon the most important toxic effects is difficult. However, major advances have been made in providing needed information about the cellular uptake and effects of heavy metal particles by the work of Costa and coworkers. In a recent study, animal cells were

utilized to compare the localization of chromosome damage induced by chromium and nickel compounds. Such studies along with earlier studies on DNA breakage and phagocytization show very clearly that much new information can be obtained for heavy metals and how these agents add to the burden of damage to human genetic material and nuerological processes.

Analytical Markers For Effects of Exposure to Environmental Agents

A major requirement for risk assessment is a routine marker to determine with minimum cost the degree of exposure of the human population to environmental agents. Such markers were being investigated but baselines were difficult to establish and much more needs to be accomplished to add to the accumulated data base. Failure to initiate such a program can delay by many years the developmental research on biological marker systems. The lack of developmental research on biological markers is one reason that the collection of biological materials was delayed. Metallothionein gene expression has been examined extensively by Karin and coworkers including studies on the structure and tissue-specific expression of the human gene. These studies demonstrate that metallothionein may be a very useful biological marker for the response to exposure to certain heavy metals especially cadmium. Molecular biological studies are urgently needed to establish the application and validity of various biological marker systems.

Conclusion

Additional basic and applied research will be cost effective in risk assessment and risk management if the funding and long range goals are stabilized. Previous reseach support has been very successful in providing badly needed data and insight for the overal objectives and responsibilities of the Environmental Protection Agency.

General Conclusions

Genetic Toxicology

1. The use of other biological systems, to assess risk to the germ cell or risk of cancer in humans, such as Drosophila, because the induction, processing and repair of DNA is different in Drosophila compared to humans lead us to undestand that the data collected with the Drosophila system extrapolated to humans would not be a good system to use in assessing at-risk-exposure to humans.

2. Studies on structure-activity for at-risk evaluations for environmental toxic substances using contemporary methodology was not productive. Support of investigations by artificial intelligence systems produced predictive as well as mechanistic tools that can be used in risk evaluation that are more reliable and predictive than structure activity studies.

3. The application of research results that contribute to risk assessment were developed in the Carcinogenicity Prediction and Battery Selection Method, (CPBS). The CPBS is now presently used by the National Toxicology Program to interpret short-term test results.

4. The "combined testing protocol" (CTP) was supported by this Agency in the grants program to pioneer these efforts. Presently, these systems are used universally in the National Toxicology Program to evaluate hazard to man.

5. The influence of non-random specific site modification of genomic DNA by environmental toxic substances of human cellular DNA may lead to more serious consequences of cellular dysfunction than random modification of cellular DNA and should be seriously considered by the Agency as a biological endpoint.

6. The critical step in establishing the initiated cell may be the processing of the site-specific damage to the cellular DNA. Subsequently, the risk may be associated with individuals inability or ability to repair these gaps.

7. The grants program has supported also the assessment of damage in assorted human tissues as well as repair of that damage. Our understanding of these results should lead to a better understanding of risk management during acute and chronic exposure.

8. New tests developed by grant support provided the scientific community with procedures to measure occupational exposure as well as passive exposure to cigarette smokers.

9. The development of a cell-cell communication system supported by this Grants Section has led the Agency to recognize that induction of epigenetic mechanisms may lead to cancer. Moreover, such epigenetic mechanisms have been suggested to explain neurotoxic disorders as well. The support for this pioneering work lead to the Agency support for a workshop on Risk Assessment Methodology of Tumor Promoters.

Neurotoxicology

1. Funding in this area should be expanded to cover multidisciplinary studies.

Organ Toxicity

1. Several projects have been supported over the existence of the general solicitations program addressing how different organs respond to exposure to environmental toxic substances. The results to date suggest that the biological responses to these environmental substances are varied and complex. There is also species differences in their response. For example, cats do not contain pancreatic butyrylcholinesterase and would not be a suitable model to use for evaluation of pancreatic dysfunction to measure acute responses to pancreatic directed metabolism of environmental toxic substances.

2. If one were to chose rat liver to measure the environmental risk following exposure to either 7,12-DMBA or 3-MCA one would obtain metabolite data that would not be applicable to human exposure. Human lung and/or skin the primary lines of defense do not metabolize either of these compounds.

3. Biological modeling to investigate the role of pesticides in our environment has been supported in a functional fashion.

Anecdotal Results

1. Exposure to environmental toxic substances and measurement of the genotoxicity using different species to quantitate the response has resulted in the realization that the different test systems do not respond to induction, processing and DNA repair in the same manner from Drosophila to man. This had led to the tier approach for evaluating environmental toxic substances by the EPA and NTP.

2. The use of artificial intelligence has been a useful tool for the EPA to use both as a predictive and a mechanistic tool. This tool supported by the grants program has wide use in the EPA and NTP assessment program.

3. The results from the combined testing protocol have pioneered the use of batteries of assays in combination and useful protocols used by NTP to evaluate environmental carcinogens.

4. Data recently gathered by the efforts supported by this program highlight the fact that the nature of the lesion in the DNA is more important than the random non-specific modification by the metabolized environmental toxic substances. These eforts have also discovered that the removal of this damage will create a nucleotide gap that will be filled by another nucleotide thereby, leading to the expression of a mutagenic or genotoxic event. These technologies can be used to identify individuals at high risk.

5. Support by this grants mechanism has contributed to an understanding that different human organs are at different levels of risk when exposed to an environmental toxic substance. (Risk assessment)

6. A striking example how the support of basic research affects regulatory decisions; the EPA grants solicitation sponsored studies on cell-to-cell communication (epigenetic systems) led EPA to support a recent workshop for Risk Assessment Methodologies for the measurement of non-genotoxic tumor promoters.

7. Support of neurotoxicological studies have led the agency to recognize that altered behavioral results can be measured by changes in physiological endpoints.

8. The applicants supported by the grants program investigating pesticide metabolism and action, the results indicate that different organs metabolize these compounds differently.

9. Currently, results from the support of basic research of environmental toxic metals, tumor initiators and analytical markers suggest that these efforts have not been supported long enough to yield definitive recommendations but are promising.

10. Support of the human cell work has led the research to the level where human cell systems can for the most part accomplish the same goals that animal systems do to measure genotoxicity, metabolism and organotypic

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responses to environmental toxic substances.

11. Basic support of the immunotoxicological responses to environmental toxic substances created a base of knowledge that produce the basic information for the draft of an RFA for a more indepth probe into immunotoxicology.

12. The studies of Goodale (R808516-010) on the effects of orgnophosphate insecticides on the pancreas have provided a model to study acute pancreatitis in humans.

13. The UCLA studies on chronic obstructive respiratory disease (R808620) have not only provided much information on the effect of air pollution on human respiratory function but they have contributed to the development of methodologies for epidemiological studies of this type. In this latter regard they may be regarded as landmarks in the field.

14. Other Values: Support of R811072-010 has helped develop one of the better regional training centers for biochemical toxicologists, that at the University of Mississippi Medical Center. This program is now supported by training and research funds from several agencies.

United States Environmental Protection Agency
Office of Research and Development Washington, DC 20460

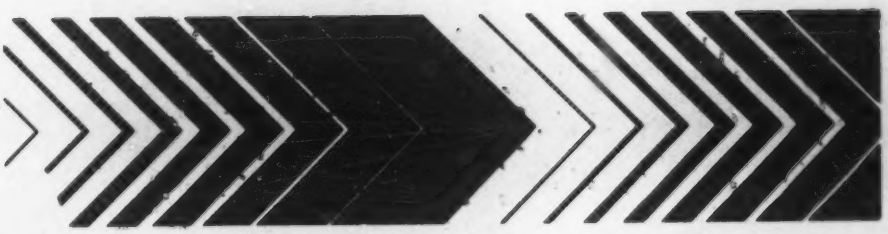
EPA

Research Grants Program

IMPACT REPORT

Environmental Biology

March 1988



PREFACE

The U.S. Environmental Protection Agency's Office of Research and Development (ORD) established the Research Grants Program within the Office of Exploratory Research (OER) in 1980. The objective of this program is to develop an effective means to stimulate extramural scientists to work on EPA's technical problems, to complement existing EPA programs and to provide a stronger creative base for mission-oriented research needed for the Agency's regulatory and enforcement purposes. To date, through its Research Grants Program, OER has supported approximately 600 research projects in priority areas of enviornmental health, environmental biology, environmental engineering, environmental chemistry/physics (air) and chemistry/physics (water).

In October 1987, OER initiated a reivew and evaluation of the investigator initiated research grants program. This was accomplished by two mechanisms. One was an idependent assessment conducted by the American Management System of the program's role in Federal environmental research, and to identify opportunities for improvement. The report of this assessment is avaiable from OER. The other was the preparation of reports by the Chairmen of peer review panels on the impact of the competitive research grant program in their discipline area. This is one of those reports.

Evaluation of the Projects Supported by the Program in Environmental Biology

Report Prepared for the

Office of Exploratory Research
U.S. Environmental Protection Agency

by

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INTRODUCTION

The Environmental Biology Research program has supported a broad range of environmental research during the years 1980 1986. For the writing of this review and evaluation report, a sub-panel of members grouped the many publications by media, discipline or special topics of broad interest. The various publications covered areas of study in risk assessment, ecosystem structure and function, toxicology, biotechnology, biological fate and transport, Great Lakes and wetland systems.

A reading of the resulting publications provides remarkable evidence for the consistency of vision by the hundreds of different panelists in the program over the period. Panelists recommended, and OER funded, proposals which focused on the outstanding problems already identified as well as some new and emerging environmental problems of regional and national scope.

Algal Toxicology and Physiology

A necessary component in assessing the impact of toxic chemicals on primary productivity is a comprehensive data base that quantifies the response of algal taxa to chemical exposure. With support from the Grants Program, Rachlin and co-workers at the Miami University, Ohio, developed experimental protocols and measured the effects of cadmium, copper, lead, and zinc on the growth rates of several freshwater and marine taxa. The Program has also funded the development and application of assays that measure the effects of herbicides on algal growth and reproduction (Cain and Cain 1983). Continued support of these projects appears necessary for estimating the ecological risk posed by toxic chemicals. Dependable support for these studies has not been historically available from other federal funding agencies.

The Program has also funded research aimed at detailing the physiological mechanisms that translate toxic chemical exposure to the observed response. For example, Rachlin and colleagues examined changes in ultrastructure in the cyanobacterium Anabaena flos-aqua resulting from exposure to cadmium. In addition to identifying lethal exposure concentrations, these investigators measured the cellular compartmentalization and incorporation of the metal and developed hypotheses concerning the mode of toxicity and the mechanisms for detoxification of accumulated cations. This work importantly noted that sequestering metals in

polyphosphate bodies not only reduced the toxicity of the metal to the organism, but also provided a mechanism for the accumulation and movement of toxic metals through aquatic foodwebs. Study of the detailed physiology of the algae may provide information useful in determining the fate of organic pollutants in aquatic systems. For example, Sicko-Goad's elucidation of the ecological factors that influence lipid content of diatoms may be useful in predicting the accumulation of lipophilic organic toxicants by these organisms and the subsequent transport and bio-accumulation.

Detailed studies of changes in algal morphology may be useful in assessing algal exposure to trace metals. Sicko-Goad and Stoermer, Great Lakes Research Division, University of Michigan, employed quantitative morphometric analyses of physiological and physical cell compartments of freshwater diatoms to measure the effects of trace metal contamination. Their work demonstrated changes in vacuole volume, number of mitochondria, and presence of membranous organelles within the vacuoles. Measurement of these characteristics might serve as useful indicators of algal exposure to trace metals.

Basic Algal Ecology

The Grants Program has supported important, basic ecological research on the phytoplankton. This work complements and provides context for the more detailed

toxicological studies. With Program support, Schelske and co-workers at the Great Lakes Research Division, Univeristy of Michigan, developed a model of the interactions between phosphorus enrichment and silica depletion as they control diatom production and algal species composition in the Laurentian Great Lakes. Using this model, the investigators were able to explain measured changes in the diatom flora associated with the cultural eutrophication of the Great Lakes. This work, in combination with toxicological research on isolated species of diatoms, for example Rachlin et al., begins to provide for the integration of basic ecologic and toxcology necessary for predicting and assessing ecological risk. The Grants Program offers the unique capability of supporting both basic and applied work of this kind. The Program fosters the necessary integration of pure and applied research needed for development of scientifically defensible regulatory policy.

Integration of basic and applied algal research, supported by the Program, is further evidenced by the work of Sicko-Goad and Lazinsky, Great Lakes Research Division, University of Michigan, who measured the effects of lead exposure on several representative algal taxa under variable phosphorus conditions. Their results demonstrated that the differential sensitivity of algal taxa to lead must be considered in the context of changing phosphorus availability to make realistic predictions of the effects of lead (and

presumably other trace metals) on primary production and species composition of the algae.

Evolution of PCB Resistance in Algae

Cooper and her colleagues at the Marine Science Research Center, SUNY-Stony Brook, have demonstrated the development of PCB-resistant strains of several estuarine diatom taxa in the Hudson River-New York Bight area. This work further showed that clones of two diatom species actually grew more rapidly in the presence of PCB. With Program support, these investigators have also examined changes in the ecological growth characteristics associated with development of PCB resistance. The Grants Program, through efforts such as these, provides the unique opportunity to examine the implications of natural selection and evolution on organism response to toxic chemicals in the environment.

Historical Changes in Algal Flora

Assessments of anthropogenically related changes in species composition of the phytoplankton requires knowledge of pre-disturbance community structure. Stoemer and co-workers examined sediment cores collected from Lake Ontario and described historical changes in the diatom flora. Changes in species composition that marked the influence of European settlement and activity within the basin were evident from detailed multivariate statistical analyses of diatom remains

preserved in the sediment cores. Continued efforts of this kind will provide the necessary historical background for evaluating current changes in species composition. The research additionally improves upon available methods for collection and analysis of data in sediment cores, thus contributing to our basic research capabilties in the area of paleolimnology.

Population Models and Risk Analysis

Support from the EPA Grants Program sponsored the development of age-structured population models of fishes (e.g., Hudson River striped bass) for use in estimating ecological risk for example Ginzburg and colleagues at SUNY-Stony Brook, New York. Using Monte Carlo simulation methods, the authors present ecological risk as the probability of quasiextinction for logistic models of fish population growth. Analyses were performed to quantify the sensitivity of risk estimates to variability associated with the mean growth rate of the fish and the amplitude of environmental variability. The resulting models and methods provide the basis for formulating reasonable and useful estimates of risk to fish population growth posed by anthropogenic disturbances (e.g., toxic chemicals, waste heat). This research provided for the application of theoretical population models to applied problems relevant to the EPA activities concerning the effects of toxic chemicals and pesticides on populations.

The Grants Program has also supported high quality research in the development and application of population models for the flour beetle (Tribolium castaneum). Desharnais, the Rockefeller University, New York, examined the implications of integrating Lotka-Volterra population models with a single locus weak selection model; this work contributed to the continued, important integration of theoretical population ecology and population genetics. Using this integrated model, Desharnais characterized the effects of natural selection on population growth of Tribolium. The results of this work have important practical applications in the area of genetic resistance developed by pest insects to pesticides. In a similar modeling study, Desharnais and Liu examined the behavior of a population model wherein fecundity and survivorship of each age-class were exponential functions of age-class density. Model results compared favorably with measurements made on laboratory populations of Tribolium. The model identified conditions where laboratory populations might be expected to undergo behaviors ranging from stable equilibria to demographic limit cycles.

Analysis of Community Stability

The Grants Program suppported ecological research that examined the utility of methods for qualitative stability in the description (loop analysis) of marine plankton

communities by Lane and Wright and Lane, the Bedford Institute of Oceanography, Nova Scotia. This work was published in Ecology, one of the more prestigious and selective technical journals in this field. Loop analysis has also been used in the examination of marine benthic systems by Puccia, SUNY-Stony Brook, and Levins, Harvard University. These innovative methods permit estimation of the likelihood of persistence of populations interacting in highly connected foodwebs using qualitative information concerning the effect of one population on another. Implications of the addition or deletion of a population from the community on the overall stability of the community can be readily calculated using these methods. The loop analysis methods were also applied in the description of the implications of anthropogenic modification of community structure on longterm community stability by Puccia and Bennet. These methods of qualitative modeling provide valuable complements to the complex, data intensive simulation models used in describing community dynamics. These works appeared in primarily in the Journal of Theoretical Population Biology, a prestigious technical journal.

Anecdotes

The age-structured stochastic fish population models and associated methods for risk analysis developed by Ginzburg and collagues, SUNY-Stony Brook, have been implemented in an

interactive computer program (RAMAS). This tool was used extensively in an EPA sponsored workshop (November 1986, Baltimore, Maryland) aimed at identifying useful models for ecological risk analysis.

Other Values

Results of research sponsored by the Grants Program are further communicated throughout the scientific community in oral presentations. For example, Dr. Susan Riechert, University of Tennessee, reports that she has discussed her EPA sponsored research at least 19 times in the past two years in her capacity as a National Lecturer for Sigma Xi.

Sea Surface Microlayer Contamination

The sea surface microlayer, that is, the upper 50 um of the water column forms the boundary layer between the atmosphere and water column. All of the airborne substances on or in water bodies have to pass through this layer, which, due to its high fatty acid content, has the capacity to retain these substances for varying periods of time. Heavy metals, pesticides, petroleum hydrocarbons, phythalates and other non-polar compounds have been shown to be concentrated in the microlayer. Once concentrated in the microlayer, the contaminants may be degraded by microbes or sunlight and become readily available to the food chain via the phyto- or zooplankton, or they may act as acute and possibly chronic toxicants to organisms living in the neuston when they come

into direct contact with the surface. The latter exposure route holds true for pelagic fish eggs which, depending on their buoyancy and the weather conditions, may float directly at the sea surface. Demersal eggs deposited intertidally may come into contact with the microlayer during low tides when egg masses are exposed and the microlayer settles on the eggs.

The possible toxicity of contaminated sea surface microlayer to marine fish embryos has been studied by Richard M. Kocan (University of Washington). He found that contaminated sea surface microlayer may be toxic to Atlantic cod (Gadus morhua), Baltic herring (Clupen harengus) and turbot (Psetta maxima). The studies suggest that surface microlayer contamination may have a detrimental effect on natural fish populations by impairing recruitment where surface microlayer contamination is high.

Sediment Contamination

Sediments are an important component of aquatic ecosystems. Sediments provide a habitat for rooted aquatic plants, microfauna and meiofauna. They serve as an adsorptive sink for metals and organics; conversely, sediments serve as a source of pollutants which can flux into the water column. Sediments also serve as an important site for the transformation and degradation of contaminants by abiotic and biotic processes. An understanding of the

biological, chemical and physical interactions that occur in sediments is fundamental when trying to evaluate anthropogenic pollution in aquatic ecosystems.

The Office of Exploratory Research has funded a number of studies which have addressed various aspects of sediment contamination. Dr. John J. Ney (Virginia Polytechnic Institute and State University) has evaluated the patterns of accumulation of toxic heavy metals which are generated by automotive traffic, and subsequently deposited in the sediments of roadside streams. Dr. Michael P. Shiaris of the University of Massachusetts-Boston has determined the concentration and distribution of anthropogenically-produced polycyclic aromatic hydrocarbons (PAH) in surficial sediments of Boston Harbor. He has also studied the biotransformation rates of three model PAHs in Boston Harbor sediments. Dr. John J. Lech (Medical College of Wisconsin) has measured the bioconcentration kinetics of two hydrophobic industrial contaminants (1,2,4-trichlorobenzene and hexachlorobenzene) in selected tissues of fish to determine the importance of sediment-bound contaminants which flux into the water column in aquatic systems. The sensitivity of critical life stages of marine benthic microfauna exposed to oil drilling muds has been established by Dr. John J. Lee of the City College of New York. These data have been used by the Agency in their assessment of drilling mud effects on the marine ecosystem.

Predicting Toxicity from Chemical Structures

A large number of man-made chemicals enter the aquatic environment from such sources as industrial and municipal discharges, nonpoint source run-off, and atmospheric deposition. A number of chemicals (dozens have been identified; many more have not been characterized) have the potential to be toxic to various aquatic organisms. In addition to the chemicals presently entering the environment, hundreds of new compounds are being produced each year. EPA has the responsibility of protecting the environment from existing and new toxic chemical.

It is not practical from a cost and time standpoint to test the toxicity of all chemical compounds. Thus, methods to predict the toxicity of various groups of compounds are of interest to the Agency. Dr. T. Wayne Schultz of the University of Tennessee-Knoxville has been awarded two Office of Exploratory Research grants to develop ecotoxicological quantitative structure-activity relationships (QSAR) for selected pyridines and phenols. He has developed models related to various structural aspects of the molecules to predict the toxicity of the compounds to phytogenetically diverse organisms.

Wetlands

Wetlands are a valuable natural resource. Wetlands are habitat for many unique plants and animals. However,

historically, they have suffered substantial losses due to drainage for agricultural utilization, and filling for urban development. Realization of their ecological and practical values has increased the need for better understanding of how they function, their roles as processors of anthropogenic materials and the impacts of cumulative effects on their structure and function. A number of projects funded by OER have addressed these needs. Examples of projects which have made significant scientific contributions follow.

Kelman Wieder of Villanova University and Gerald Lang of West Virginia University have investigated the use of natural and man-made wetlands to treat metal containing acid mine drainage. They have investigated the effects of metals on Sphagnum and the chemical/physical mechanisms of metal retention in peat. Thus, their research has examined the practical utility of using natural and/or man-made wetlands containing peat to remove harmful metals from acid mine drainage. In addition it has elucidated the basic chemistry of the interactions of metals with the ion exchange capacity of peat. The results of their research shows that wetlands have potential for minimizing the impact of mine drainage on stream water quality. However, consideration must be given to the physiological requirements of the plant and microbial communities in wetlands if they are to function effectively as a treatment system for the removal of metals from acid mine drainage.

Barbara Bedford and colleagues at Cornell University funded by OER have addressed a critical problem facing the nation's wetlands - the impacts of cumulative effects on wetland structure and function. They developed concepts and methods for evaluating cumulative effects on three basic wetland ecosystem functions: flood storage, water quality and life support (species diversity). The results of this research project provide resource managers and decision makers with a means of addressing a critical problem. The approach is being used by resource planners at all levels of government.

Nonpoint Source Pollution

Nonpoint source pollution associated with agriculture, mining, silvaculture, and urban runoff contribute to the degradation of water quality in many rivers and lakes. Nonpoint source pollution because of their diffuse nature are more difficult to assess and control than point source pollution from industrial and municipal dischargers. Considerable progress has been made in controlling point sources of pollution. However, for nonpoint source pollution to be adequately addressed an understanding of the impacts of various land uses on water quality and quantity needs to be established. Likewise, evaluation of Best Management Practices (BMP) for controlling nonpoint source pollution is needed. Research funded in the Environmental Biology Program

have addressed these needs. A research project which has made a significant contribution to understanding agricultural nonpoint source pollution is that of Dr. Robert VanKeuren at The Ohio State University.

Dr. Robert W. VanKeuren conducted research examining the effects of agricultural practices on surface and subsurface hydrology, nutrient export, soil loss and water quality. His research has contributed significantly to the development of a better understanding of the impact of various cattle grazing programs on nonpoint source pollution loadings. In addition, he has evaluated the impacts of fertilization practices on nonpoint source pollution loadings. The results of his research have demonstrated the effects of various agricultural practices on water quality and quantity. They have broad implications for the establishment of agricultural Best Management Practices (BMP) for reducing nonpoint source pollution.

Microcosms and Multispecies Testing

Historically, chemicals have been evaluated for their potential to cause adverse effects on aquatic life using single species toxicity tests (i.e., Daphnia magna, fathead minnow, etc.). These tests do not measure effects on the interactions of organisms as they occur in nature and do not provide information on the effects of chemicals on the functional properties of ecosystems.

Pioneering research to address these issues has been conducted by Dr. John Cairns, Jr. at Virginia Polytechnic Institute and State University. Dr. Cairns and his colleagues have developed multispecies toxicity test systems using naturally derived microbial communities on polyurethane foam substrates to assess the potential adverse impacts of chemical contaminants. This research provides evidence of effects on emergent properties of systems not available from studies of individual species. The results of studies on zinc, chlorine and atrazine show effects on communities may occur at chemical levels similar to effects on sensitive single species. The advantage of the multispecies tests over single species tests is that they can provide predictions of community or system components most at risk.

Another research program headed by Dr. Richard H. French of the University of Nevada has demonstrated that microcosms can be a cost-effective method for assessing reservoir water quality and for designing reservoir restoration programs which require the identification of the limiting nutrient. Dr. French placed microcosms <u>in situ</u> in Lahontan Reservoir in Nevada to investigate changes in phytoplankton species composition in response to additions of the nutrients nitrogen, phosphorus and the phosphorus precipitant aluminum sulfate. The microcosms proved effective in providing guidance on the probable response of the phytoplankton community to various waste treatment alternatives to control

eutrophication of the reservoir. The research provided a valuable method to assist water resource managers in making decisions about alternative means of controlling eutrophication. This approach is currently widely used.

Dr. French in a related OER funded project investigated the utility of in situ microcosm from calibrating dynamic water quality models. The results show that in situ microcosms can provide an inexpensive and quick method of calibrating dynamic lake water quality models. This capability is important since it means that the identification and design of cost-effective eutrophication restoration programs for lake and reservoirs can be accomplished more efficiently by providing more accurate coefficients for input into the dynamic models used to evaluate alternatives.

Toxicology Methods and Conditions

Appropriate, reliable methods are the foundation for accrual of meaningful results. Documentation is a key issue in methods because it allows valid comparisons of results among laboratories and also between laboratory and field.

Basic pharmacokinetic work by William Hayton (Washington State University) and co-workers has demonstrated significant effects of temperature and metabolism inhibitors on accumulation in rainbow trout of a much-used plasticizer (di-2-ethylhexyl phthalate; DEHP). DEHP exposure and

accumulation in food sources such as trout is of concern because phthalates are known promoters of carcinogenesis that may also interfere with reproduction.

Basic work by David Warshawsky (University of Cincinnati) and co-workers has demonstrated that the wavelength of light to which green algae are exposed can affect the sensitivity of the algae to environmentally present polycyclic aromatic hydrocarbons (PAH), significant pollutants that result from incomplete burning of many organics. Warshawsky's work is, in fact, some of the first to demonstrate that non-mammalian (and non-bacterial) organisms can interact in a significant way with PAH to produce genetic mutagens. These studies indicate potentially significant effects on algae themselves and upward through the food chain in other species.

W. Wang has demonstrated millet seeds to be more sensitive than those of cucumber, lettuce, radish, red clover or wheat, the current varieties recommended by EPA and OECD for detection of pollutant effects in plant development. Further, he found significant differences in concentration sensitivity between root elongation and duckweed growth inhibition, another commonly used test system.

The above examples in basic methods and conditions, showing significant effects of temperature, light and choice of organism, highlight the importance of all such factors in the success of environmental investigations. In addition, it

should be recognized that useful basic data was simultaneously obtained.

New areas: Toxicology of Immune Responses

Immunologic defense is critical to the survival of complex organisms. Consideration of the effects of xenobiotics on such defense mechanisms is a rapidly developing and significant area.

R. Hinsdill (University of Wisconsin) and co-workers have shown decreased resistance and increased mortality of mallard ducks to infection by avian cholera after exposure to oil (crude and marine fuel), oil dispersant (detergent) and mixtures of the two. This immunosuppression occurred in ducks that outwardly appeared quite normal and indicates that wildlife exposed to oil spills, even treated oil spills, may survive quite well until challenged. Other work by Hinsdill and co-workers includes demonstration of age-dependent immunotoxicity in rats caused by TCAOB, a product formed in the environment from chloraniline herbicides and related to TCDD, one of the dioxins. Other plant growth regulators (chlorocholine, maleic hydrazide, glyphosine) and xenobiotics, together with nutrition status were shown to decrease several parameters of immune competance. Hinsdill's data and methods form the basis for needed future studies.

Studies by B.S. Roberson (University of Maryland) and co-workers have demonstrated inhibitory effects of

pollutants, including heavy metals, on immune cell responses of trout and oysters, indicative of decreased ability to withstand infection. These effects occurred without significant direct toxicity by the chemicals. Roberson, et al. established and characterized a chemiluminescence assay for both trout phagocytes and oyster hemocytes that will be very useful for future studies.

In summary, immunotoxic agents have significant ability to affect survival of organisms. Knowledge of such effects is thus important to an understanding of the long-known increased morbidity and mortality in environmentally stressed organisms.

Genetic Toxicology

Like immunotoxicology, genetic toxicology is relatively new and rapidly changing. The implications of toxicant effect at the level of chromosomes/DNA, i.e., mutagenesis, are many, including reproductive failure, carcinogenesis or tumor promotion and even death. Application of rapidly developing technologies to non-human systems is beginning to clarify some subtle ways in which toxicants influence environmental residents.

Pioneering work by R.M. Kocan and co-workers (University of Washington, School of Fisheries) has demonstrated that contaminated sediments as well as individual chemical pollutants can cause chromosomal aberrations in fish cells as

well as in fertilized fish egg systems. The latter offer the particular advantage of continued study through hatching and growth so that consequences of the chromosomal changes may also be observed. Kocan et al. have recently used flow cytometry, a new and powerful technique, to define the active cell cycle phases in which effects occur.

A "Microscreen" Assay has been developed by T. G. Rossman and co-workers (New York University Medical Center, Institute of Environmental Medicine). This screen uses easy to grow, well characterized E. coli and tests for both mutagenicity and direct toxicity. This assay has been put into use by a number of investigators, including the EPA's Genetic Toxicology-Health Effects Lab in Research Triangle Park, and it has been proposed for use in at least one other country.

Additional work by T. Rossman and co-workers has demonstrated significant synergism (comutagenesis) for combination exposures. Their work also suggests that mutagenesis results from incorrect synthesis and/or repair.

In other studies, R.M. Petters and co-workers (St. Bonaventure University) have shown lethal dominant genetic lesions in a wasp reproductive assay. The unusual but well-documented reproduction characteristics of this wasp allow detection of the stage of damage and thus it could become a useful screening system with additional documentation.

Work by Wei at al (University of Florida) has shown that the routine practices of water and wheat flour chlorination produce significant quantities of mutagenic compounds. Such routine practices may thus have genetic consequences yet to be identified but clearly suggested by this work.

In summary, genetic toxicology studies funded by EPA have contributed significant technology as well as significant data. In particular, the technology has been accepted and used by other investigators and EPA itself.

The Impact of Pollutants and Toxicants on Biochemical Processes in Soil and Water

The work of D.G. Capone and colleagues at SUNY at Stony Brook (in aqautic systems) is astonishing in both quantity and quality as is that of Gunther Stotzky at NYU (using soil microflora). Even the methodology papers are useful to others working with the same materials for different purposes as, for example, the paper by McDaniel and Capone (J. Microbiol. Methods [1985] 3:291-302) on comparing different procedures for separating aquatic bacteria from sediments for subsequent direct enumeration. That need to recover, identify and enumerate was shared by M. A. Gealt of Drexel University, Gunther Stotzky of NYU, Inga Mahler of Brandeis, Martin Alexander of Cornell, and Gabriel Bitton of the University of Florida at Gainesville.

Applied Genetics, Especially the Fate of Microorganisms Introduced into a New Environment or Microcosm

Here the problem is one of following a particular organism or a particular genetic element which may have been introduced with the xenobiotic form and been dispersed via various genetic mechanisms to the indigenous microflora.

There are truly seminal papers by Gealt of Drexel University who used E. coli carrying a plasmid containing the herpes simplex virus gene for thymidine kinase to follow the dispersion among the indigenous flora of a waste water treatment plant of a genetically engineered DNA sequence (GEDS); and by Stotzky of NYU who used a eukaryotic Drosophila gene sequence in a prokaryotic plasmid to follow the fate of GEDS in soil. These are exciting and elegantly conceived tools used in the study of an important applied problem: the fate of genetically engineered microorganisms and DNA sequences in the environment whether intentionally or accidentally released. Mahler at Brandeis has examined the expression in E. coli of a foreign chromosomal gene, in this case the mercury resistance gene cloned from B. subtilis, confirming again in the laboratory intergeneric gene expression. Another important area of applied genetics is that illustrated by the work of Valla (at Oakland University in Michigan, who has examined the degradation of toxicants by specifically engineered or selected bacterial species.

The Use of Sludges and Consequences of Such Use for Soil Reclamation

These projects reflect interest in a major problem as municipalities seek sites for sludge disposal; receiving communities, while wanting to restore mined lands, are concerned with long-term impact on soil use, groundwater quality and health. Here, William Sopper and his co-workers at Pennsylvania State University continue their study of long-term site stabilization (as determined by populations of bacteria, fungi, and actmonycetes). Lawrence Kapustka and colleagues at Miami University in Oxford, Ohio have studied the effects of sewage sludge and metals on the mycorrhizal fungal plant symbionts that increase uptake of water and nutrients into their host plants. The obverse of this, the use of wetlands for wastewater treatment (rather than the use of the wastes for soil reclamation), was examined by Bitton's group at the University of Florida at Gainesville.

Re-examination of the Potential of Biological Control of Plant Pathogens and of Weeds

These projects are a response to the prevalent heavy use of chemicals as herbicides and pesticides.

L. E. Casida, Jr. at Pennsylvania State University has reported on the survival of *B. thuringiensis* spores and the insecticidal parasporal crystals in soil, while Harris and co-workers at the University of Wisconsin-Madison have

described assays for and methods of optimizing spore-carrying capacity of Colleotrichum gloeosporioides, a potential herbicide (for Myriophyllum spicatum and other weeds).

Responses of Terrestrial Vegetation to Gaseous Pollutants

The most important and productive research projects funded in this area by OER dealt with the effects of gaseous pollutants on plants. Ambient ozone (O_3) is now recognized as the regionally distributed gaseous air pollutant most likely to suppress productivity of both forests and agricultural systems. O_3 is classified as a criteria pollutant by the EPA and this agency re-examines the O_3 standard, on the basis of biological data, at regular intervals. S. Eversman (University of Montana) has studied the effects of O_3, PAN, and SO_2 on lichens because this plant group is thought to be the one most sensitive to gaseous pollutants. Results showed O_3 concentrations well below ambient levels caused significant reductions in photosynthesis, starch build-up in chloroplasts, and change in the structure of chloroplast membranes. SO_2 and PAN concentrations required to produce similar changes were three-fold higher than O_3 concentrations used. Thus, the idea that plants are more likely affected by O_3 than other gaseous pollutants was verified.

A highly productive project funded by OER has used techniques in biotechnology to learn about mechanisms of O_3

damage in cells as well as to clarify the process of genetic control of cellular enzymes. Damage to plants from O_3 is thought to occur because O_3 destroys cellular membranes resulting in the production of free radicals. The free radicals produced by membrane destruction are also phytotoxic and plants can protect themselves from O_3 damage by increasing the activity of free radical scavenging enzymes. Dr. J.G. Scandalios (North Carolina State University) has shown that increased activity of free radicals scavenging enzymes following chemical and heat stresses results from the increase in free radicals in cells. Increases in activity of these enzymes is caused by elevated production rates of the enzymes via stimulation of their synthesis from DNA code. Experiments have shown isoenzymes of free radical scavenging enzymes exist compartmentalized in the cytoplasm, mitochondria, and chloroplast so that cells can respond to increases in free radicals at any site. This work has led to the isolation of the genes for a free radical scavenging enzyme from the chloroplast, its cloning, and subsequent mapping in which the sequence of nucleotides and amino acids were revealed. The possibility that tools in biotechnology could now be used to move genes which protect plants from O_3 between plants now exists.

Another important NER project with gaseous pollutants showed that SO_2 can cause foliage to emit gaseous hydrocarbon molecules. Foliar emissions of these compounds are of

interest because they may be used as a bioindicator of SO_2 stress and suggests mechanisms of SO_2 toxicity. T. Kimmerer (University of Kentucky) has shown that SO_2 absorbed by leaves turns cells slightly acidic which favors anaerobic forms of respiration. This shift in respiratory pathway results in the foliar emission of acetaldehyde and ethanol. If SO_2 is the only acidifying agent, then ethanol emissions from foliage would be specific to the presence of SO_2 in air. Field measurements of ethanol emissions from foliage verify the viability of this biomonitoring approach, and the next phase of research will be to associate ethanol emissions from leaves with ambient SO_2 concentrations.